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Advance Report of Committee 30—Impact and Bridge Stresses

D. S. BECHLY, *Chairman*

Static and Fatigue Tests on Prestressed Concrete Railway Slabs

by

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Static and Fatigue Tests on Prestressed Concrete Railway Slabs

SYNOPSIS

This report is principally concerned with the fatigue properties of prestressed pretensioned concrete members. A theoretical study of the fatigue resistance of such members is first presented, followed by a description of laboratory tests on six beams. A discussion and interpretation of the test results constitute the balance of the report.

The proposed theory of fatigue failure is based on three diagrams, which are combined to enable the investigator to predict the critical loading. One of these diagrams is a failure envelope based on a limited amount of fatigue test data on prestressing strands. This envelope indicates the permissible range of steel stress (from any given minimum value) to obtain fatigue failure at 1,000,000 load cycles. A second diagram pertains to the fatigue characteristics of plain concrete, and is similar to the failure envelope for the prestressing steel described above. The application of the two failure envelopes is accomplished by combining them with curves expressing the moment-stress relationship for a given beam. (See Fig. 1).

The 6 test beams were 19 ft long, 16½ in wide, and 18 in deep, and were pretensioned with 11 strands of ½ in nominal diameter to 60 percent of their ultimate strength. The beams were cast end-for-end on the same prestressing bed, and all beams were cast during the same operation; however, the concrete strengths were intentionally varied. In each of the three pairs of beams the compressive cylinder strengths at time of test for beam pairs A and B, C and D, and E and F were, respectively, 8850 psi, 7730 psi, and 5750 psi.

The beams were tested in pairs, with one beam undergoing static tests and the other fatigue tests. The test program for the static specimens, beams A, D and F, consisted of loading each beam in increments to the design moment, sustained load tests at design moment, sustained load tests at cracking moment, and finally a gradually increasing load to failure. The static failure loads at each of the two load points for beams A, D and F were 59,900 lb, 55,900 lb, and 53,900 lb, respectively, compared with a design load of 19,040 lb. (See Tables 4, 5, and 6).

Fatigue tests were conducted on beams B, C, and E where the repeated loading was applied at 250 cycles per minute. In the case of beam B, the test program consisted of 1,000,000 cycles where the load applied by each of the two jacks varied from 3,000 lb to 20,000 lb, and 1,000,000 cycles with load range from 4,000 lb to 26,000 lb, so as to produce cracking, and 1,516,100 cycles to fatigue failure with the load range from 4,000 lb to 30,200 lb, making a total of 3,516,100 cycles of load. In the testing of beams C and E, the first 2,000,000 cycles were applied exactly as for beam B; however, for beam C the fatigue failure occurred after 970,500 cycles of load ranging from 4,000 lb to 30,300 lb, and for beam E the fatigue failure occurred after 954,000 cycles of load ranging from 4,000 lb to 28,900 lb.

The test results checked reasonably well with the critical fatigue loads predicted on the basis of the stated theory of fatigue failure.

INTRODUCTION

In 1953 the research staff of the Association of American Railroads, in connection with the assignments of AREA Committee 30—Impact and Bridge Stresses, began laboratory and field investigations for the purpose of comparing the behavior of cer-

tain pretentioned prestressed bridge slabs and similar slabs of conventional reinforced concrete. In this regard, tests were carried out on full-size bridge slabs to obtain information on the shear, bond, deflection and ultimate strength properties under static and repeated loads.

The investigation reported herein is an outgrowth of the work described above and is principally concerned with the fatigue properties of prestressed members. The size of the six test specimens was limited, in this investigation, by the capacity of the equipment available for dynamic testing; it was thus not possible to test full-size bridge slabs. Since the slabs in question had simple, one-way reinforcing, the tests were carried out on full length strips of convenient width with steel percentages and prestress similar to those in the slab.

The test beams were produced and furnished by Prestressed Concrete of Colorado, Inc., Denver, Colo., and were tested at Fritz Engineering Laboratory, Lehigh University. The prestressing strands used in the test members were contributed by John A. Roebling's Sons Corporation. Instrumentation was conducted at the plant by members of the Lehigh staff and members of the AAR research staff.

THEORY OF FATIGUE FAILURE

Introduction

Without the medium of a theory of fatigue failure for interpretation, test results can have only very limited applicability and usefulness in the development of design criteria. It is, therefore, convenient to consider at this stage theoretical aspects of fatigue failure in prestressed concrete beams.

Data on the fatigue strength of metal specimens are usually presented in two forms, namely (1) the S–N diagram, which plots the number of cycles of loading to produce failure for any given stress variation and (2) a modification of the theoretical Goodman–Johnson diagram which indicates the stress variations at all levels of stress which can be applied an infinite number of times without causing failure. The modified Goodman–Johnson diagram, which indicates the endurance limit at any level of stress, is the one more often needed for design.

In reinforced concrete and prestressed concrete members it is possible for fatigue failure to take place either in the tension steel or in the concrete compression zone. The modified Goodman–Johnson diagram for both of these materials can be incorporated into a combined diagram for the purpose of predicting the ultimate strength in bending of a critical cross section under repeated loading. The combined diagram will be discussed in the following paragraphs.

The Combined Diagram

The combined diagram, shown in Fig. 1, is found by combining the fatigue failure envelopes for the concrete and steel with curves giving the relation between applied bending moment and stresses for the beam itself. Thus one is able to ascertain the possible range of moment which can be applied to the beam without causing fatigue failure in either the steel or the concrete.

Fatigue Failure Envelope for the Steel

The failure envelope curve which appears as diagram A of Fig. 1 is the modified Goodman–Johnson diagram obtained for prestressing strand similar to that used in the manufacture of the beams tested in this investigation. This envelope indicates how much the stress can be increased from a given lower level to obtain a failure at 1,000,000

load cycles. It should be noted that the ordinates and abcissas of this curve, as well as all others in Fig. 1, are given as percentages of the static ultimates of the quantities being considered. It can be seen, for example, that the steel may resist a repetitive range of stress amounting to 28 percent of static tensile strength if the lower limit is zero, but only an 18 percent range of stress if the lower stress limit is increased to 40 percent. The basing of the fatigue failure envelope on 1,000,000 load cycles appears to be sound; however, there is only a limited amount of data presently available on the fatigue properties of strands.

Fatigue Failure Envelope for Concrete

A diagram similar to the steel fatigue failure envelope is shown as diagram D (in Fig. 1) for high-strength concrete in compression. This curve, however, has been continued into the tension quadrant to enable the fatigue cracking loads to be determined. The curve given here was first obtained by Ros[1] and has been checked by cylinder tests in connection with fatigue tests of prestressed beams.[2]

Curves Showing Relationship Between Bending Moment and Stress

Diagrams B and C in Fig. 1 indicate the variations of the stress in the prestressing steel and the top and bottom fiber concrete stresses, respectively, with the applied bending moment in a prestressed concrete beam. The curve segments to the left of the cracking moment are established without difficulty through the use of conventional design practice.* It is observed that the relation between stress and moment is linear from zero load to the cracking load. Beyond the cracking load the stresses must be determined by a trial and error calculation using equilibrium and compatibility conditions at the various stages of loading. The procedure is explained fully in Appendix B. A simplification of the calculation for design purposes is suggested in a following section of this report.

Use of the Combined Diagram

When the diagrams and curves of Fig. 1 are prepared for the beam under consideration, the range of loading to produce fatigue failure of either concrete or steel at 1,000,000 cycles of repeated load may then be determined. It is implied that the lower limit for this range is design dead load and the upper limit is defined as the "ultimate strength under repeated load." Considering first the possibility of fatigue failure in the steel, a horizontal line is projected from the dead-load point B on the stress-moment diagram to the corresponding point C on the steel failure envelope. Projections from point C vertically to D, then from D horizontally back to E and F on the steel stress-moment diagram, yield the value of the ultimate strength under repeated load based on fatigue in the steel. A similar procedure is followed through points G, H, I, J and K to determine the ultimate strength under repeated load based on fatigue failure in the concrete. The lower of these two moments, which in Fig. 1 is that corresponding to fatigue failure in the steel, is the critical ultimate strength under repeated load of the member. Cracking moments under repeated loadings may also be calculated by a similar use of the figure, considering in this case the concrete bottom fiber stress and the tension quadrant of the concrete stress envelope (tracing points L, M, N, O).

[1] See page 30 for all references.

[*] See Appendix A.

LABORATORY TESTS

Specimens

The details of the specimens and of the full-size bridge slab are shown in Fig. 2. All 6 test beams were 19 ft long, and 16½ in wide by 18 in deep and had prestressing tendons consisting of 11 strands of ½ in nominal diameter. The percentage of prestressing steel in the slabs was 0.625, whereas in the test beams it was 0.532. Thus, the effective prestress in the specimens was less than in the bridge slabs by a slight amount.

Properties of the Concrete

The specimens were cast in pairs, and a different concrete strength was used for each pair. Apart from the variation in the concrete strength, the six specimens were identical.

Details of the concrete strengths are as follows:

TABLE 1—PROPERTIES OF CONCRETE IN TEST BEAMS

Beam	*Compressive Cylinder Strength at Release of Prestress in PSI*	*Compressive Cylinder Strength at Time of Test in PSI*	*E_c at Time of Test in PSI**
A, B	5,700	8,850	4,610,000
C, D	4,800	7,730	3,790,000
E, F	3,200	5,750	3,180,000

*Modulus of elasticity as obtained from cylinder tests at time of beam test.

Properties of the Prestressing Strands

The 7-wire high-tensile steel strands used in the manufacture of the test beams had a cross-sectional area of 0.1438 sq in and an ultimate strength, as determined by actual tests on strand samples, of 38,800 lb which corresponds to an ultimate stress of 270,000 psi. These strands were rated at an ultimate strength of 250,000 psi in the manufacturers' catalogue.

Fatigue tests were carried out on two samples of this strand. To provide a satisfactory means of loading the wire in the testing machine, the ends were gripped in mild-steel pipes, partly by the action of wedge anchorages and partly by bond with high-strength cement-mortar grout. The results of the tests are given in Table 2.

TABLE 2—FATIGUE TESTS OF TWO SAMPLES OF ½ IN DIAMETER PRESTRESSING STRAND

Number	*Minimum Stress in PSI*	*Maximum Stress in PSI*	*Rate in Cycles per Minute*	*Number of Cycles to Failure*
1	140,000	174,000	500	1,147,000
2	140,000	174,000	500	1,360,000

The fatigue failure envelope of diagram A in Fig. 1 is assumed to be valid for ½ in diameter prestressing strands in spite of the fact that the envelope was originally based on numerous tests of ⅞ in diameter strands. This assumption was made because of the close correlation of the data of Table 2, with corresponding data for ⅞-in

strands. In fact, the data of Table 2 will plot directly on the failure envelope curve of diagram A, if the catalogue-rated ultimate strength of 250,000 psi is used as a basis.

The test beams were poured in one prestressing bed on the afternoon of March 28, 1957, and were steam cured until the morning of March 30, at which time the prestress was released. The first testing began 40 days after pouring and continued for 35 days thereafter.

Camber

The camber of the beams was measured when the prestress was released and again at the time of testing.

TABLE 3—OBSERVED CAMBER OF TEST BEAMS (ALL VALUES IN INCHES)

Beam	*A*	*B*	*C*	*D*	*E*	*F*
After release of prestress	0.16	0.18	0.17	0.16	0.19	0.19
At time of test	0.24	0.21	0.22	0.23	0.25	0.27
Change	0.08	0.03	0.05	0.07	0.06	0.08
Average Change	0.055		0.060		0.070	
Time in days*	61	66	53	54	37	38

*Time elapsed from release of prestress to time of testing.

Test Program

The two beams comprising each pair were tested during the same period of time, one beam being a static and the other a fatigue test specimen. Both static and fatigue test beams were symmetrically loaded with two jacks 5 ft 6 in apart and had centers of supports 18 ft apart. The repeated loading was obtained using Amsler pulsating equipment[8] with 110,000-lb capacity jacks. Fig. 3 shows a beam being tested under repeated loading at the left and a second beam statically loaded at the right. The nature of the repeated loading is such that the load applied by the jacks is a sinusoidal function of time, with the maximum and minimum load being held constant by proper adjustment of the machine.

Static Specimens

The testing program for the static specimens (beams A, D, and F) consisted of the loading of each beam, in increments, to a load of 20,000 lb on each jack. This load, which is slightly above the computed design load* was then released. In the following step the jack load was reapplied in increments to 20,000 lb and sustained for 48 hr before release. The beam was next loaded to just above the cracking point, after which this load was maintained for 48 hr. Finally, after 24 hr rest, each beam was tested to failure.

Fatigue Specimens

In the case of the fatigue specimens, a static test was first made to the load of 20,000 lb per jack followed by 500,000 cycles of loading varying between 20,000 lb per jack maximum and 3,000 lb per jack minimum. After a second static test and an

* See Appendix A.

TABLE 4—LOADING SCHEDULE FOR BEAMS A AND B

($f_c' = 8850$ at time of test)

Static Tests—Beam A

Date	*Load Stage*	*Load P in Pounds*	*Description*
5/31/57	1-S	Zero to 20,000 to zero	Initial static test
5/31	2-S	Zero to 20,000	Sustained load of 20,000 lb for 48 hr
6/3	2-S	20,000 to zero	
6/3	3-S	Zero to 28,000	Static test to cracking
6/3	4-S	28,000	Sustained load of 28,000 lb for 48 hr
6/5	4-S	28,000 to zero	
6/6	5-S	Zero to 59,900	Ultimate load test

Fatigue Tests—Beam B

Date	*Load Stage*	*Load P in Pounds*	*Description*
6/5/57	1	Zero to 20,000	Initial static test
6/5	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
6/6	2	Zero to 20,000	Second static test
6/6	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
6/8	3	Zero to 28,000	Third static test
6/8	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
6/9	4	Zero to 28,000	Fourth static test
6/9	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
6/11	5	Zero to 32,000	Fifth static test
6/11	3-D	4,000 Min to 30,200 Max	Rep. load, 500,000 cycles
6/13	6	Zero to 32,000	Sixth static test
6/13	3-D	4,000 Min to 30,200 Max	Rep. load, 500,000 cycles
6/14	7	Zero to 32,000	Seventh static test
6/14	3-D*	4,000 Min to 30,200 Max	516,100 cycles to failure

*Total cycles of 3-D loading = 1,516,100.

additional 500,000 cycles of loading as before, a static test was made to determine the cracking load. Then, 1,000,000 cycles of dynamic loading were applied with the minimum of 4,000 lb and the maximum equal to 26,000 lb. In the final stage the fatigue strength of the specimens was calculated for 1,000,000 cycles of loading, and each specimen was then loaded to a value near the computed fatigue strength for a number of cycles sufficient to cause failure. In all repeated-loading operations, however, the testing was interrupted at the end of every 500,000 cycles to permit the running of static tests to determine the static components of strain and deflection. The details of the loading schedule of each beam are given in Tables 4, 5, and 6.

Upon completion of all testing, the beams which had undergone fatigue failure were subjected to an examination of strand breakage. As a preliminary step, all concrete in the region of the broken strands at the failure crack was removed and the strand actually exposed for approximately a distance of 6 in either side. After visually checking the condition of each strand all seven in the lower two rows of the section were removed by means of a cutting torch.

TABLE 5—LOADING SCHEDULE FOR BEAMS C AND D

($f'_c = 7{,}730$ psi at time of test)

Static Tests—Beam D

Date	*Load Stage*	*Load P in Pounds*	*Description*
5/24/57	1-S	Zero to 20,000 to zero	Initial static test
5/24	2-S	Zero to 20,000	Sustained load of 20,000 lb for 48 hr
5/26	2-S	20,000 to zero	
5/26	3-S	Zero to 28,000	Static test to cracking
5/26	4-S	28,000	Sustained load of 28,000 lb for 48 hr
5/28	4-S	28,000 to zero	
5/29	5-S	Zero to 55,900	Ultimate load test

Fatigue Tests—Beam C

Date	*Load Stage*	*Load P in Pounds*	*Description*
5/23/57	1	Zero to 20,000	Initial static test
5/23	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
5/24	2	Zero to 20,000	Second static test
5/24	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
5/26	3	Zero to 26,000	Third static test
5/26	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
5/27	4	Zero to 26,000	Fourth static test
5/27	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
5/29	5	Zero to 32,000	Fifth static test
5/29	3-D	4,000 Min to 30,300 Max	Rep. load, 500,000 cycles
5/30	6	Zero to 32,000	Sixth static test
5/30–31	3-D*	4,000 Min to 30,300 Max	470,500 cycles to failure

*Total cycles of 3-D loading = 970,500.

Instrumentation

Strain Measurement on Steel at Release of Prestress

Prior to the pouring operation SR–4 electrical resistance strain gages of Type A–12 were placed on the prestressing strands at the midpoint and near the ends of all specimens. The locations are shown in Fig. 4. Readings were taken on these gages before and after release of prestress to determine the bond length of the end block required to anchor the prestressing strands. Complete results are given in Appendix C.

Measurement of Strand Slip During Testing

In the first pair of tests (beam E and F) Ames dial gages were attached at each end of the beams to the prestressing strands comprising the bottom layer of the prestressing steel. Throughout the tests, readings were checked for indications of strand slip. Since no slip was indicated either by the gages or by the SR–4 gages attached to the steel, the slip gages were not used in other tests.

TABLE 6—LOADING SCHEDULE FOR BEAMS E AND F

($f'_c = 5{,}750$ psi at time of test)

Static Tests—Beam F

Date	*Load Stage*	*Load P in Pounds*	*Description*
5/8/57	1-S	Zero to 20,000 to zero	Initial static test
5/8	2-S	Zero to 20,000	Sustained load of 20,000 lb for 48 hr
5/10	2-S	20,000 to zero	
5/10	3-S	Zero to 28,000	Static test to cracking
5/10	4-S	28,000	Sustained load of 28,000 lb for 48 hr
5/12	4-S	28,000 to zero	
5/13	5-S	Zero to 53,900	Ultimate load test

Fatigue Tests—Beam E

Date	*Load Stage*	*Load P in Pounds*	*Description*
5/7	1	Zero to 20,000	Initial static test
5/7	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
5/9	2	Zero to 20,000	Second static test
5/9	1-D	3,000 Min to 20,000 Max	Rep. load, 500,000 cycles
5/11	3	Zero to 26,000	Third static test
5/11	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
5/12	4	Zero to 26,000	Fourth static test
5/12	2-D	4,000 Min to 26,000 Max	Rep. load, 500,000 cycles
5/14	5	Zero to 32,000	Fifth static test
5/14–17	3-D	4,000 Min to 28,900 Max	Rep. load, 954,000 cycles to failure

Strain Measurement on Concrete at Midspan

In both static and fatigue tests concrete strains were measured at midspan on the top fibers and at the level of the lower layer of prestressing steel. Fatigue strains were measured by two SR–4 type gages on the top fiber and values recorded by means of a Brush oscillograph. During the static testing of all specimens concrete bending strains were measured by a Huggenberger mechanical extensometer at two points on the top fiber and at a point on each side at a distance of 2¼ in up from the bottom fiber. This check on the strain readings was especially necessary in the fatigue tests since the gages measuring strains could not be temperature-compensated, and the static components had to be found by another means. It was for this reason that static tests were run on the fatigue test specimens after every 500,000 cycles of loading.

Measurement of Deflections

In the static loading operations midspan deflections were measured with an Ames dial gage mounted beneath the test beam. During fatigue loading the static deflection gage was taped down out of contact with the beam surface. To measure the beam deflections during fatigue loading a spring-steel cantilever was set up beneath the test beam at midspan with the displacement end of the cantilever coupled to the lower

beam surface by means of a vertical aluminum rod. The deflections were indicated by means of strain-gage readings taken from the top and bottom surface of the spring-steel cantilever and picked up with the Brush recording equipment. The apparatus for measuring deflections is shown in Fig. 5.

Results

Deflections, Strains, Permanent Sets

The steel and concrete strains observed during the various loading operations are presented in graphical form in Figs. 6 through 10. The corresponding curves of load versus beam deflections are contained in Figs. 11 through 13. Figs. 6, 7, 8, 9, 11 and 12 apply to tests of the static specimens, and from them can be seen the increase in deflections and strains and the permanent sets which resulted from the sustained static loadings. Figs. 10 and 13 contain the information concerning the fatigue specimens and indicate the effect of the repeated loadings on strains and deflections.

Cracking-Load Tests

Cracking was not detected during either the fatigue or the static tests to design load. Cracks were first found in all specimens during the static cracking-load tests as shown in Table 7.

TABLE 7—CRACKING LOADS OF TEST SPECIMENS

Beam	*Cracking Load, Lb per Jack*		*Test Run When Cracks Detected*
	Load at Which Cracks Observed	*As Obtained from Strain and Deflection Curves*	
A	23,500	26,000	3-S
B	26,000		(4)
C	20,000		(4)
D	24,500	26,000	3-S
E	22,500		(4)
F	22,900	26,000	3-S

Tension cracks first appeared in the region of maximum moment between the load points of the beams. During the periods of sustained loading on the static specimens an increase in the heights of the preformed cracks was observed, together with the appearance of a number of small new cracks. The deflections and strains and the final permanent set were all noticed to increase considerably during the sustained loading at cracking.

The effect of repeated loading on cracking was generally observed during test run (4) which was carried out after application of 1,000,000 cycles of design load (see Tables 4, 5, 6, and 7). The appearance of a number of new cracks was noted during test run (5) and subsequent runs, together with a considerable development of those cracks already present. The static strains and deflections and the permanent sets observed in these static tests, which indicate the effect of the repeated loading, may be seen in Figs. 10 and 13.

Ultimate-Strength Tests

The three static specimens were tested to failure within 24 hr after the sustained cracking-load tests had been completed. Typical flexure-type failures occurred in the pure moment region between the load points, with extensive yielding of the tension

steel followed by secondary crushing of the concrete in the compression zone. The appearance of the three beams after failure is shown in Fig. 14. Quantitative details of the strength tests on the static as well as the fatigue specimens is presented in Table 8.

TABLE 8.—ULTIMATE STRENGTH OF SPECIMENS

Beam	Static Ultimate Load		Computed Ultimate Fatigue Strength		Observed Ultimate Fatigue Strength			Types of Failure
	Computed	Observed	Min Load	Max Load	Min Load	Max Load	Number Cycles*	
A	52,000	59,900						Compressive Failure of Concrete
B			4,000	33,000	4,000	30,200	1,516,100	Fatigue Failure of Strands
C			4,000	32,600	4,000	30,300	970,500	Fatigue Failure of Strands
D	50,300	55,900						Compressive Failure of Concrete
E			4,000	31,400	4,000	28,900	954,000	Fatigue Failure of Strands
F	45,750	53,900						Compressive Failure of Concrete

Note: All loading is given in terms of pounds per jack. The cylinder strength of the concrete in Beam Pairs A-B, C-D, and E-F at time of test was 8,850, 7,730, and 5,750 psi, respectively.

*Number of cycles shown were preceded by 1,000,000 cycles of load ranging from 3,000 to 20,000 lb, and by 1,000,000 cycles of load ranging from 4,000 lb to 26,000 lb. See Tables 4, 5, and 6.

All fatigue specimens failed by breakage of the prestressing strands in the lower two rows. Little forewarning of the fatigue failure was given, as the deflections and strains in the beams did not reach large values, even at failure. Imminence of failure was signified by the development of a larger crack at the prospective failure section. As the repeated loading continued, sharp reports were heard which indicated the snapping of the individual wires of strands. Fig. 15 shows the crack development on both sides of the three fatigue-test beams during the last stage of loading (test run 3–D).

Fatigue failure of the beams was considered to have taken place when the first wires broke. As the load cycles were continued after failure, more wires were heard to break, and the maximum load, corresponding to the maximum induced deflection, gradually dropped off. Upon the release of load, the crack pattern at the failure section did not close to the extent that it did at other sections.

After failure, all beams were loaded with the design load. Even in the failed condition all six beams could support the static design loads, but the corresponding deflections were large, being about 1½ in. in the static specimens and 1 in for the dynamic specimens. After the failure of the static specimens by crushing of the concrete compression zone, the lower portion of the beams were sufficiently intact to act as doubly reinforced members and resist the design load. Failure of some of the bottom strands in the fatigue specimens left the upper portion of the beams with sufficient steel at mid-depth to resist design loading. Fig. 16 shows the six test beams after failure, with the higher strength members uppermost in both photographs.

ANALYSIS OF TEST RESULTS

The analysis of test results has been subdivided, for the sake of clarity, into subsections concerned with deflections and strains, cracking loads, influence of concrete strength, fatigue strength, creep considerations and simplification of fatigue strength calculations.

Deflections and Strains

The load-deflection curves for the static sustained-load tests are shown in Fig. 11 for beams A, D, and F. The amount of permanent set in the beams and the amount of increase in deflection under sustained load is greatest for the beam of lowest strength concrete (beam F). An indication (in Fig. 11) that the amount of creep is inversely proportional to the strength of the concrete is further borne out in Fig. 7, indicating the strains of the concrete in the top fiber under sustained loading. If one now looks at Fig. 13, which shows consecutive static load-deflection curves for the fatigue test beams; and Fig. 10, showing the strains in the top fiber for the same tests, it will be seen that the creep is of the same order of magnitude for the static and fatigue test beams. The fatigue-test data are conclusive evidence that considerable creep occurs in the concrete under repetitive loading as applied in the laboratory test. The effects of the creep of the concrete on the steel stresses is discussed in some detail in a following section of this report.

The amount of residual deflection, as observed in Fig. 11, does not seem excessive for any of the three statically tested beams. Table 9 shows values of residual deflection which were measured after completion of test run 4–S and the corresponding recoveries which occurred before starting test run 5–S.

Table 9 shows that there is a substantial decrease of residual deflection with increasing strength.

TABLE 9—RESIDUAL DEFLECTIONS AND RECOVERIES FOR STATIC BEAMS

	Beam A		*Beam D*		*Beam F*	
	Time Date	*Defl. Inches*	*Time Date*	*Defl. Inches*	*Time Date*	*Defl. Inches*
Completion Test 4-S	2:00 pm	0.0530	9:40 am on 5/28	0.0700	3:05 pm on 5/12	0.0940
Commence Test 4-S	8:30 am on 6/6	0.0335	9:45 am on 5/29	0.0465	1:30 pm on 5/13	0.0630
Elapsed Time, Hours	18.5		24.1		22.4	
Recovery, Inches	0.0195		0.0235		0.0310	
Percent Recovery	37		34		33	

The magnitude of residual deflections for the three dynamically tested beams follows approximately the same trend as outlined above for the static beams. Fig. 13 shows, for example, that residual deflections at the commencement of test run (5) were measured at 0.0165 in, 0.0415 in, and 0.1508 in for beams B, C, and E, respectively.

Figs. 6 and 8 show the average results of strain measurements taken on two of the bottom layer strands at midspan for the statically tested beams. The curves denoted as test runs 2–S and 4–S exhibit a marked increase in steel strain during the periods of sustained load. In general, this increase in steel strain is caused by a differential

creep in the concrete at every section, resulting in a gradually increasing moment carried by the steel (see Appendix D). The remarkable recovery of strain after application of run 4–S is probably due to the beneficial action of the cracks which opened up at the high loads and tended to reduce the tensile creep strains in the lower fibers of the concrete. The direct translation of the steel strain into steel stress is complicated by the fact that strain is being measured with respect to the longitudinal axis of a single wire of a strand. This creates some uncertainty about what modulus of elasticity should be assumed for obtaining steel stresses from the measured strains and points up the necessity for making a series of special calibration tests. However, an E value of 28,000,000 psi should give reasonable values.

Consideration of the load-deflection curves for the fatigue test beams given in Fig. 13 shows that there is no appreciable change in slope prior to fatigue failure of the strands. This is true because the maximum stress in the strands is below the proportional limit of the steel. There was also no significant increase in the observed amplitude of the deflection under repeated load as shown by the Brush recorder.

Figs. 14, 15, and 16 are photographs showing the crack pattern on all beams at impending failure or after failure. One observation, which is not discernible in the photographs, is that the relation between applied jack load and crack number and size was approximately the same for both beams of a given strength of concrete. In the case of the fatigue specimens, the opening and closing of cracks during cycles of loading could be observed, although these cracks always seemed to close at the minimum load of each cycle up until failure. The fatigue failure was always preceded by the formation of one rather pronounced crack which seemed to open wider under load than any of the others. The failures were not accompanied by excessive deflections, and hence the failures might be termed sudden in nature. It was generally observed that the prestress was sufficient in all cases to close, after failure, the tensile cracks which developed during the testing of the three static beams. In the case of the fatigue specimens the cracks were all closed after release of failure load except in the region of strand breakage. In Fig. 16, an arrow denotes the failure crack in beams B, C, and E, and these cracks can be seen in greater detail in Fig. 15.

Cracking Loads

Table 7 indicates a negligible difference in the observed cracking loads for the six beams tested. Two means of distinguishing cracking load were employed—one involving a visual inspection of the white-washed surface of the beams, and a second method wherein non-elastic behavior was observed from plotted strain and deflection data. The first method simply consisted in an examination of the beam at 2000 lb load increments for visible cracks. The second method required an arbitrary decision as to what point the load-deflection (or load-strain) curves deviated from a straight line.

Remarks Concerning Use of Modulus of Rupture

The normal manner of calculating the cracking load of a member is to find the load which will produce a stress in the bottom fiber of the member equal to the rupture modulus of the concrete. From this approach it would seem that the cracking load should be greater for the higher strength concrete because the rupture modulus of that concrete would certainly be higher. No rupture modulus tests were made, however,

Using the rupture modulus to calculate cracking load sometimes gives good results because several of the fallacies involved tend to counteract each other under some conditions. First of all, rupture modulus is a very specific test made with a standard plain concrete beam under a specified loading condition. The results of this test cannot be

applied directly to a plain concrete specimen of different cross section or to one which is reinforced because the influence of shrinkage stresses is different in each case. Differences in the size, shape, or amount of reinforcement will affect the magnitude of the tensile stresses near the surface caused by shrinkage. Furthermore, in determining the ultimate strength of a beam as limited by the compressive strength of the concrete, the calculation is never made on the basis of a maximum compressive stress using elastic theory. It cannot be expected, therefore, that this method would be satisfactory for concrete in tension. Failure of concrete in either tension or compression must be calculated by taking into account the plastic properties of the concrete. The presence of steel on the tension side of the beam makes it difficult to treat this problem because the plastic properties of the concrete are altered by the reinforcement. The concrete undoubtedly cracks when the strain in the steel reaches a value which is mostly independent of the strength of concrete involved.

Level of Prestress

An important variable which affects cracking load is the level of prestress at the time of loading. It would seem that all six test beams should have the same loss of prestress because of their similarity, but this is not necessarily true. The modulus of elasticity of the concretes is not greatly different, so the elastic loss of prestress upon transfer of prestress should be about equal for all beams. On the other hand, the loss of prestress for the higher strength beams due to shrinkage will be greater than for the lower strengths because the amount of shrinkage is approximately proportional to the water content. However, the loss of prestress due to creep of the concrete would be largest for the lowest strength concrete. Since no measurements were made to determine loss of prestress, conclusions regarding this item cannot be made, but it is possible that there was a difference among the six beams.

Concrete Strength

A consideration of the influence of concrete strength on certain beam properties will be dealt with at this point. This includes a discussion of concrete strength as it affects flexural strength under static loads, bending stiffness, and bond. The effect of concrete strength on the ultimate strength under repeated load of the test beams has been noted previously.

Effect on Flexural Strength Under Static Load

The calculated and observed values of static ultimate strength show that increasing the concrete strength makes very little difference in the ultimate strength of the member (see Table 8). The difference in the failure loads between the strongest and the weakest beams is only 11 percent while the corresponding difference in concrete strength is 55 percent. The reason for this can be explained by considering the internal resisting couple at ultimate load. If one considers two test beams which are identical except for strength of concrete, it can be shown that the center of pressure of the normal force acting on the concrete at any section will be closer to the top fibers for the stronger beam. This is because the compression stress block for the stronger beam will more closely approximate a triangular shape than will that of the weaker concrete, thus resulting in a larger moment arm for the stronger beam under given load. It follows that the corresponding increase in moment must be small because the increase in the moment arm will be small. Actually, the test results tend to show a larger advantage for the higher strengths of concrete than do the calculated values. However, this is partly due to the fact that beam A was loaded from zero to ultimate

over a period of 1½ hr whereas about 2 hr were consumed in loading beams D and F to the ultimate.

Calculations for the static ultimate moments based on the 1958 recommendations of the ASCE–ACI Joint Committee on Prestressed Concrete give reasonably good agreement between calculated and observed ultimate moments.[4] In calculating the ultimate moments, it was assumed that the centroid of the steel area and the position of the resultant strand force were coincident. This assumption is not quite correct; however, it is on the safe side. The three beams actually failed statically by crushing of the concrete in the top fibers. Fig. 14 shows the three beams after failure. The calculations for ultimate moment are given in Appendix A.

In order to take advantage of the higher strength concrete to obtain higher ultimate moment in a beam the arrangement of steel must be changed and the beam designed using the higher permissible prestress in the concrete. With the higher design stresses the strands can be placed nearer to the bottom fiber of the beam and, therefore, the moment arm of the resisting moment will be increased and result in a corresponding increase in ultimate moment.

Effect on Bending Stiffness

The effect of concrete strength on the bending stiffness of the beams is shown in Figs. 11 and 12. The increase in stiffness is not proportional to the increase in concrete strength, because the modulus of elasticity is not proportional to the compressive strength for high-strength concrete. The effect of strength of concrete on the concrete strains is shown in Figs. 7, 9, and 10. Table 10 shows the modulus of elasticity obtained from cylinder tests, load-deflection curves, and strains measured on the beams.

TABLE 10—MEASURED VALUES OF MODULUS OF ELASTICITY FOR CONCRETE

	Modulus of Elasticity (Millions of PSI)					
	Beam A	*Beam B*	*Beam C*	*Beam D*	*Beam E*	*Beam F*
Cylinder Tests	4.61	4.61	3.79	3.79	3.18	3.18
Load-Deflection	4.57	4.58	4.35	4.46	3.78	3.91
Strains Top Fiber	4.44	4.12	4.17	3.83	3.83	4.33
Strains*	4.13	----------	4.88	4.23	4.48	4.39

*On the concrete at level of lower row of steel.

Effect on Bond

A number of observations were made during the course of the tests which reflect on the bonding characteristics of the strands. One of the most important of these is the fact that the strain readings taken on the steel strands near the ends of the beams indicate that the bonded length required for the anchorage of strands did not change for any of the six beams. Strain readings on the steel were taken at release of prestress, and during the various stages of testing as well.

The anchorage of a 7-wire strand such as the ones used in these beams is mostly a mechanical wedging effect resulting from the Poisson's Ratio effect in the steel, shrinkage of the concrete, and the necessity of the steel to untwist in order to slip. Because of the mechanical nature of the bond it appears only necessary to have con-

crete of good density in the vicinity of the strand, and compressive strength appears to be of little importance within the range of compressive stresses being considered here.

Fatigue Strength

The calculated ultimate strengths under repeated load were all based on failure of the steel prestressing strands. The calculated ultimate strength under repeated load based on concrete failure was higher in all three cases than the corresponding values based on the steel. All three fatigue-test beams actually failed by rupture of the strand. Fig. 16 shows beams B, C, and E after failure by repeated loading. The large cracks, at sections where strands failed in fatigue (see also Fig. 15), did not close upon removal of the load, whereas all other cracks in the beams closed after failure. All three statically tested beams failed by compression of the concrete after a noticeable plastic elongation of the strands.

The correlation between theory and test results is quite good the greatest difference being 9.3 percent.* The only disturbing fact is that the theory is not conservative in any case. The question arises as to whether or not the theory might be even less conservative if some other cross section of member were involved, and if the discrepancy between theory and test results might not become so large for a particular section as to render the method invalid. The best approach to the answer of this question is to try to determine the cause of the discrepancy, and this is done in one of the following portions of this report.

An examination of the extent of strand fractures in the beams subjected to dynamic loading was carried out, and the results are shown in Fig. 17. It was evident in every case that the primary cause of failure was due to breakage or partial breakage of the prestressing tendons. All beams experienced wire breakage of some strands in the bottom layer and to a lesser degree in the second layer. It will be noted that damaged strands were fairly well distributed in the cross section. In no case did the concrete in the region of the top fibers appear to be on the verge of compressive failure. Fig. 18 is a close-up view of five exposed strands in beam B. The strands are numbered 1, 5, 2, 3, and 4 (in accordance with Fig. 17) reading from top to bottom. It will be seen that strands 1, 2, 3, and 4 are ruptured, whereas strand 5 appears to be intact.

Creep Considerations

Test results presented in Figs. 7 and 10 indicate that the amount of creep of the concrete under repeated loading was comparable in magnitude to the creep in the corresponding static specimen. This is substantial proof that when repeated loading is applied continually, as in the laboratory testing, considerable creep occurs in the concrete.

The effect of creep of concrete on the steel stress for a beam loaded only by a prestressing force is well known. A relatively large portion of the loss of prestress in any prestressed concrete beam is due to creep of the concrete because it greatly exceeds in magnitude the amount of creep in the prestressing steel. Suppose that a sustained load such as dead load or sustained live load were applied to a prestressed member. This causes creep in the lower portion of the beam in exactly the opposite direction as that caused by the prestressing force. Whereas prestressing caused a greater shortening of the bottom fibers than of the top, the sustained loading causes a greater lengthening

* See Table 8.

of the bottom fibers than for the top fibers. The creep of the concrete under sustained loading is opposite to the creep of the concrete due to prestress alone. The result is that creep of concrete under sustained load results in an increase of steel stress in the same way that creep of concrete under prestress alone resulted in a loss of prestress.

The theory for predicting fatigue failure did not take into account any creep of concrete. The theory did, however, point to the steel as the critical material in all cases. The mathematical analysis of the effect of creep of concrete on the steel stress, given in Appendix D, applies for sustained loading; however, it also applies in the case of repetitive loading continuously applied.

It should be noted that at high repeated loads, the critical cross section will be cracked, and for this reason there will be a progressive increase in steel stress under sustained repetitive loading. This increase in the steel stress produces a larger total tensile force in the cross section, and from a consideration of equilibrium there must then be a greater total compressive force on the cross section. This increase in the total compressive force results in higher compressive stresses in the concrete. Since creep in concrete is very nearly directly proportional to the applied stress, there results an increase in creep.

Referring to the fatigue test results in Table 8, it will be noted that the same test loads were applied to beams B and C even though the concrete strength, and therefore, the predicted strength under dynamic loading was highest for beam B. It is observed that whereas beam B failed at practically the same load as beam C, beam B nevertheless withstood 545,600 cycles more than beam C. Creep of concrete in beam B was less than beam C under the same stress, and for this reason it is logical that the beam of higher strength concrete would fail eventually but would always require a larger number of cycles. Beam E, which had the lowest strength concrete, also had the lowest failure load and the most creep of the three beams.

It has been established that creep in concrete occurs when a member is subjected to a continuous repeated loading. Furthermore, even cycling at lower loads tends to cause creep in the concrete and results in a reduction of the ultimate strength under repeated load. When the cycling is intermittent, the concrete may have time to recover during the period of lighter loading, and creep of concrete would not contribute to the failure. Therefore, the test results represent a lower bound to the value of ultimate strength under repeated load, because of the continuous nature of the loading. The type of loading used in this investigation is seldom, if ever, encountered in practice; therefore, the test results obtained are extremely conservative as when applying them to, for instance, the design of bridge members. To treat the problem of creep in a quantitative way, and to evaluate the amount by which the test results are conservative, would require an extensive study into the creep properties of the concrete and probably would never yield an exact value because of the complex nature of the problem as it applies in beams.

From the foregoing discussion it would appear that the theory of fatigue failure being used here, although not conservative for predicting the behavior of the test beams, is satisfactory for predicting the behavior of beams in practice. In the case of the test results, the theory holds within 10 percent, which is of the same order of accuracy as methods commonly used for computing the static ultimate strength of a member. In view of this, it would seem that design can safely be based on this theory. Because of the laborious aspect of the method some modifications will be discussed in order to simplify it to a satisfactory design method.

If the theory of fatigue failure is applied to a number of prestressed beams chosen

at random it would appear to be seldom that a beam would fail due to concrete fatigue. It is of interest that, to date, no investigator has reported a test member failing in fatigue of concrete, and in view of the discussion presented, this is understandable. Certainly, the possibility of a fatigue failure of concrete would likely occur only in a section with low-strength concrete and high percentage of steel. On the other hand, if a minimum strength of concrete of 5000 psi is specified for members, it should not be necessary to consider the possibility of concrete failure in design.

Simplification of Fatigue-Strength Calculations

It has already been pointed out that the establishment of the relationship between stress and moment in the region above cracking load is a laborious task. However, a qualitative consideration of the properties of the materials involved leads to a simplification which can be justified for design purposes. Referring to Fig. 19 and considering the curve of stress vs moment for a reinforced concrete beam, it will be noted that the curve is linear almost to the ultimate moment and at this point becomes concave downward because the steel begins to yield. Considering a combination of high-strength concrete, which has a very small plastic portion of the stress-strain curve, and high-strength steel which has no yield point and a linear stress-strain curve almost to ultimate, it will be realized that the portion of the steel stress-moment curve which is concave downward will be extremely small or non-existent for the materials used in prestressed concrete, particularly pretensioned members. Let us now consider the curve in Fig. 19 which applies to a prestressed beam having exactly the same cross section and reinforcement as the reinforced concrete beam already discussed. Assuming that the beam begins to crack with the steel stress at point A, the curve for greater moments becomes non-linear. Because the tension force in the steel is greater than that required for the corresponding reinforced concrete beam at the same bending moment, the rate of increase in the steel stress will be less for the prestressed than for the reinforced beam. For this reason the steel stress curve in the region above cracking load must be concave upward. At some bending moment corresponding to point B, the tension forces in the two beams are equal, and from this point on toward ultimate, the tensile force is equal in both beams at the critical section.

Point C on the diagram is simply the static ultimate strengeth and can be calculated easily, as can point A. The dashed line connecting these two points is a conservative approximation of the steel curve in the vicinity of the cracking load, and can be used by the designer to obtain the ultimate strength under repeated load. The values obtained by this method, are given in Table 11 along with the calculated values and the test results. It will be seen that the approximate values are slightly more conservative than the calculated values, but are still not conservative with respect to the test results.

TABLE 11—COMPARISON OF VARIOUS VALUES OF DYNAMIC ULTIMATE LOAD

Beam	*By Test*	*Calculated**	*Approximate Method*
B	30,200	33,000	31,700
C	30,300	32,300	29,300
E	28,500	31,300	27,400

All values are maximum pounds per jack. The minimum is 4,000 lb in all cases.
*See Appendix B.

The design of members for fatigue loading has now been reduced to a simplified procedure; however, the problem of providing a sufficient factor of safety still remains.

Summary

The fact that the ultimate strength under repeated load is considerably lower than the static ultimate moment should not be taken as an indication that prestressed concrete is not well suited for fatigue loading. Since fatigue failure must be based on range of stress rather than maximum stress, it appears that prestressed concrete is far better than reinforced concrete in resisting fatigue loading.

This argument is based on the fact that conventionally reinforced concrete usually cracks at low load, thus causing a high rate of change of steel stress with respect to moment. The reinforced concrete structure in service under fatigue loading, therefore, has a much lower factor of safety than generally supposed; but this factor of safety is apparently sufficient in most cases. Because of the non-linear nature of the complete stress-moment curve for the prestressed member, the method presented herein should be used for design in the same way that the conventional design static loading is based on allowable stresses with a sufficient factor of safety as regards ultimate static moment.

Specifications usually simplify the consideration of loss of prestress to the use of an empirical formula. Some consideration should be given to the ultimate loss of prestress in members subjected to fatigue loading because of its bearing on the cracking load and ultimate strength under repeated load. It will be noted in Fig. 1 that the ultimate strength under repeated load lies uncomfortably close to the observed cracking moment. Loss of prestress will result in a reduction of the cracking moment and in fatigue strength. Previously the statement was made that the beam under repeated loading should not be cracked at design load. In order to meet this requirement, some knowledge of the ultimate loss of prestress should be known. Concrete should be so controlled as to keep loss of prestress to a minimum for members which are to be loaded with fatigue loading.

There are several reasons why a minimum compressive strength of concrete should be specified. Among these are (a) to insure good durability, (b) high density for good anchorage of strands, (c) reduce probability of fatigue failure in concrete, (d) adequate shear strength and (e) better economy of materials.

On the other hand, the tests indicate that there is a point of diminishing return on increasing the concrete strength. Although full advantage of the higher strength concrete was not taken in the design of the members, the practical aspects of manufacturing beams with these higher strength concretes would seem to outweigh the small advantages gained.

CONCLUSIONS

From the results of these tests, it appears that the following conclusions are reasonable:

(1) The theory of fatigue failure was found to be satisfactory for predicting the ultimate strength under repeated load for prestressed members. The use of a simplified method for determining the steel stress-moment diagram is satisfactory and is more conservative than the exact method of obtaining the steel stress versus moment curves.

(2) Consideration of the fatigue properties of concrete, creep of concrete, and fatigue properties of the steel strand, shows that concrete failure is improbable if the concrete strength is greater than 5000 psi.

(3) Design should be based on having no tensile stress in the bottom fiber of concrete. By checking the strength under repeated load, a sufficient factor of safety can be provided.
(4) As much as 50 percent design overload can be permitted without causing failure at 1,000,000 cycles. The static strength is approximately three times the design load.
(5) The results of the fatigue tests on beams B, C and E were lower than predicted, and this is believed due to the creep induced in the concrete by the continuous application of repeated loads.
(6) No warning of impending fatigue failure of prestressed concrete beams can be expected other than the opening and closing of cracks. However, if no visible cracks occur under load, no danger of fatigue failure exists.
(7) There was no evidence of slip of strands in any of the six beams tested. The prestress force in ½ in diameter strands is transferred to the concrete in a relatively short anchorage length.
(8) The strength of the test beams under 1,000,000 repeated loads is approximately 55 percent of their static strength.
(9) The shear strength of the beams is sufficient without additional steel.
(10) The cracking load of a member cannot be calculated with accuracy because of unknown shrinkage stresses and unreliability of the rupture modulus as a measure of tensile strength.
(11) The 5750-psi concrete used in beams E and F was of sufficient strength. The use of higher strength concrete is not advantageous unless the prestressing strands are placed to take advantage of the higher allowable stresses.
(12) In the static tests the primary cause of failure was a crushing of the concrete, whereas the primary cause of fatigue failure was breakage of steel strands.

RECOMMENDATIONS FOR FUTURE RESEARCH

Although the theory of fatigue failure presented here has been verified by these and other tests, there are some aspects which have not been investigated. Among these are:

(1) Magnitude of ultimate loss of prestress.
(2) The correlation between the lower limit of the dynamic ultimate load found in laboratory testing with the value of dynamic ultimate load for a member loaded under field conditions, in order to establish a proper factor of safety for design.
(3) Establishment of a S-N diagram for the combination of steel and concrete in flexure.
(4) Effect of poor bond.
(5) Fatigue properties of various types of steel.
(6) Concrete fatigue failure in composite sections.
(7) Shear strength.

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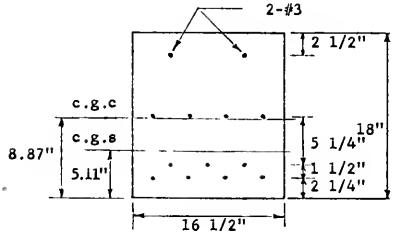
APPENDIX A—ANALYSIS OF TEST BEAMS

The calculation of working stresses for only the intermediate strength beams is shown. The values of ultimate load, however, were calculated separately for all three strengths of beams.

Data



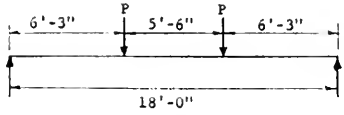
Initial strand stress before release of prestress ..... = 150,000 psi
Area of prestressing tendons 11 @ 0.1438, A_s ..... = 1.582 sq in
Modulus of elasticity of prestressing tendons, E_s ..... = 28,000,000 psi
Modulus of elasticity of concrete, E_c ..... = 4,000,000 psi
Transformed area ..... = 309.7 sq in
Unit weight of beams ..... = 307 lb/ft
Center of gravity of transformed section to top fiber, y_t ..... = 9.13 in
Center of gravity of transformed section to bottom fiber, y_b .. = 8.87 in
Center of gravity of transformed section to center of gravity of steel, e ..... = 3.76 in
Moment of inertia of transformed section, I_t ..... = 8340 in^4

Section modulus (top fiber), $S_t = \frac{8340}{9.13} \ldots\ldots = 913 \text{ in}^3$

Section modulus (bottom fiber), $S_b = \frac{8340}{8.87} \ldots\ldots = 940 \text{ in}^3$

Calculation of Design Moment

The loading for the test beams was patterned after the earlier tests of the AAR.[5] These early tests involved slabs of the same length and depth as the test beam, but were 6 ft 6 in wide. The 6-ft 6-in wide slabs were loaded as shown in the sketch below, and the load P which produced a bending moment corresponding to Cooper E 72



loading plus full impact was found to be 90,000 lb. The equivalent load for the 16½-in wide test beams is 19,040 lb calculated as follows:

$$\frac{16.5}{78} \times 90{,}000 = 19{,}040 \text{ lb}$$

The corresponding design live-load moment for the test beams is 1,425,000 lb-in. The dead-load moment, M_D is 149,000 lb-in.

Calculation of Effective Prestressing Force

Initial prestressing force, $P_o = 1.582 \times 150{,}000 = 237{,}300$ lb.

Elastic losses:

$$\Delta f_{el} = \left[\frac{P_o}{A} + \frac{P_o e^2}{I} - \frac{2}{3}\frac{M_D e}{I}\right]\frac{E_s}{E_c}$$

$$= \left[\frac{237{,}300}{309.7} + \frac{237{,}300 \times 3.76^2}{8340} - \frac{2}{3} \times \frac{149{,}000 \times 3.76}{8340}\right]\frac{28}{4} = 7860 \text{ psi}$$

Shrinkage losses:

Assuming 0.02 percent losses,
$0.0002 \times 28 \times 10^6 = 5600$ psi

Creep:

Assume twice elastic losses,
$2 \times 7860 = 15{,}720$ psi

Relaxation of steel:

Assume 4 percent losses,
$0.04 \times 150{,}000 = 6000$

Total losses of prestress = 35,180 psi
Effective prestress = 114,820 psi
Effective prestressing force = 182,000 lbs

Calculation of Working Stresses

Prestressing:

Initial top fiber: $f_c = -\frac{P}{A} + \frac{Pe}{S_t} = -\frac{237{,}300}{309.7} + \frac{237{,}300\ (3.76)}{913} = +209$

Initial bottom fiber: $f_c = -\frac{P}{A} - \frac{Pe}{S_b} = -\frac{237{,}300}{309.7} - \frac{237{,}300\ (3.76)}{940} = -1715$ psi

Dead-load stresses:

top fiber: $f_c = \frac{M}{S_t} = \frac{149{,}000}{913} = -163$ psi

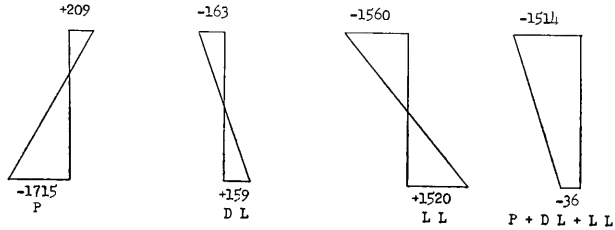
bottom fiber: $f_c = \frac{M}{S_b} = \frac{149{,}000}{940} = +159$ psi

Live-load stresses:

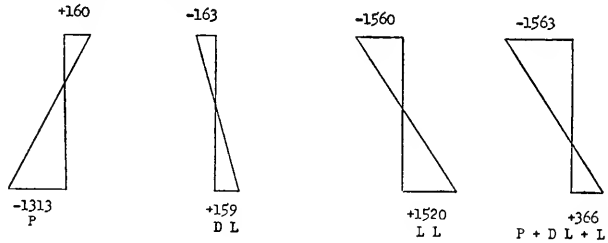
top fiber: $f_c = \frac{M}{S_t} = \frac{1{,}425{,}000}{913} = -1560$ psi

bottom fiber: $f_c = \frac{M}{S_b} = \frac{1{,}425{,}000}{940} = +1520$ psi

Initial concrete stresses:



Concrete stresses after losses:



Calculation of Static Ultimate Moment

The static ultimate moments for beams A, D, and F, were calculated through the use of the method proposed in the Tentative Recommendations For Prestressed Concrete by ACI–ASCE Joint Committee 323.[4] The relationship given, for rectangular sections is

$$M_u = A_s f_{su} d \left(1 - \frac{k_2 p f_{su}}{k_1 k_3 f'_c}\right)$$

where

$$\frac{k_2}{k_1 k_3} = 0.6$$

and

$$f_{su} = f'_s \left(1 - 0.5 \frac{p f'_s}{f'_c}\right)$$

For beams A, D, and F, the various terms in the above equations may be tabulated as shown below.

Beam	f'_c psi	f'_s psi	A_s sq in	$p = \frac{A_s}{bd}$	f_{su} psi	Computed M_u lb-in
A	8850	250,000	1.582	0.00745	224,000	4,050,000
D	7730	250,000	1.582	0.00745	220,000	3,920,000
F	5750	250,000	1.582	0.00745	210,000	3,580,000

To check the computed static load at failure against the experimental load, we may write

$$75P_{ult} + 149{,}000 = M_u$$

where 149,000 is the dead-weight moment of the beam in lb-in.

Solving, we find $P_{ult} = \frac{M_u - 149{,}000}{75}$.

The final summary is given in Table 8.

APPENDIX B—CALCULATION OF STRESSES IN A PRESTRESSED MEMBER AT A CRACKED SECTION

Consider the cross section at which the bending moment is greatest. The external moment may be resolved into a couple whose forces are equal in magnitude to the force, P_m, necessary at the level of the center of gravity of the steel to produce zero stresses in the entire concrete section. The magnitude of force P_m is

$$P_m = P + \Delta P = P + \epsilon_s E_s A_s$$

where

$$\epsilon_s = \frac{P}{E_c A_c} + \frac{P e^2}{E_c I_c}$$

P is the effective prestressing force and ΔP represents the loss of prestress due to elastic strain in the concrete.

Let the lower force of the couple be applied at the center of gravity of the steel, then the upper force acts at a distance

$$d = \frac{M}{P_m}$$

above the lower force.

Refer now to Fig. B–1. By superimposing the lower force of the couple alone on the member, the concrete stresses over the whole cross section are reduced to zero while the tension force in the steel increases by ΔP to P_m. The state of stress in the concrete due to the external moment M is thus found by analysing the case of an eccentrically applied axial load.

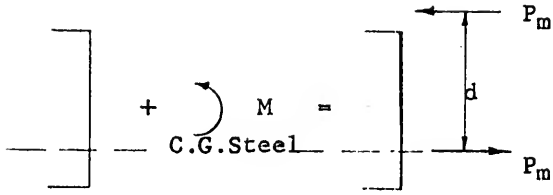
Consider now Fig. B–2, and apply the equations of statics.

$$\Sigma V = 0: \quad P_m + \int \sigma_s dA_s - \int \sigma_c dA_c = 0 \qquad (1)$$

$$\Sigma M_{P_m} = 0: \quad \int \zeta_c \sigma_c dA_c - \int \zeta_s \sigma_s dA_s = 0 \qquad (2)$$

Assuming plane sections remain plane,

$$\sigma_c = \frac{\sigma_1}{E_1} \frac{Z_c}{x} E_c \qquad (3)$$



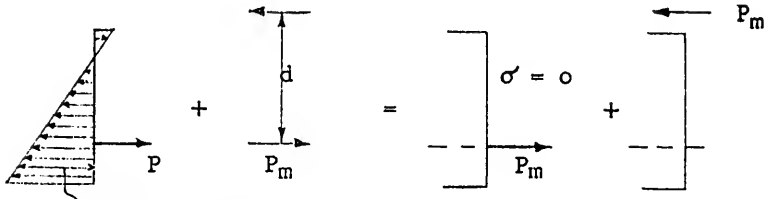


Figure B-1

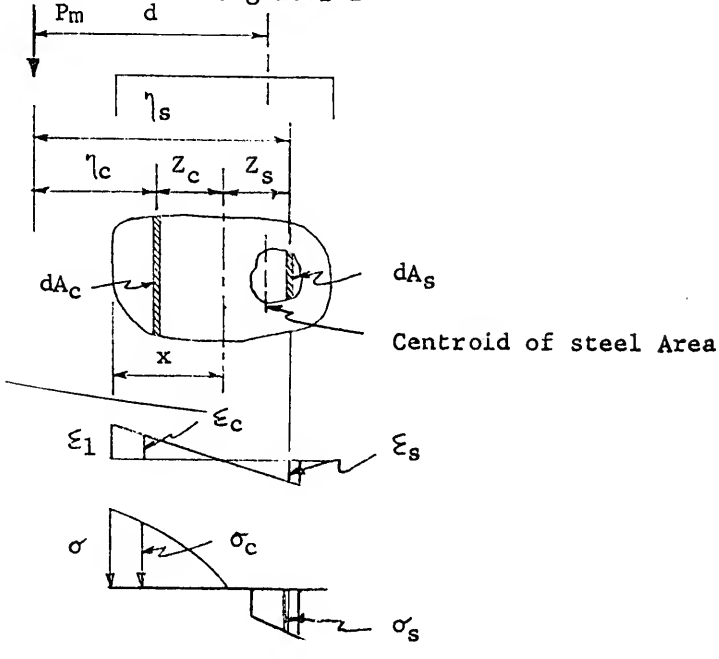


Figure B-2

where

$$E_c = \frac{\sigma_c}{\epsilon_c} \qquad (E_c \text{ is the secant Modulus of Elasticity})$$

also

$$\sigma_s = \frac{\sigma_1 Z_s}{E_1 x} E_s \qquad (4)$$

Rewriting equations (1) and (2)

$$P_m + \frac{\sigma_1}{E_1} \int \frac{E_s Z_s}{x} dA_s = \frac{\sigma_1}{E_1} \int \frac{E_c Z_c}{x} dA_c \qquad (5)$$

and

$$\frac{\sigma_1}{E_1} \int \zeta_c \frac{E_c Z_c}{x} dA_c = \frac{\sigma_1}{E_1} \int \zeta_s \frac{E_s Z_s}{x} dA_s$$

or

$$\int \zeta_c \frac{E_c Z_c}{x} dA_c = \int \zeta_s \frac{E_s Z_s}{x} dA_s \qquad (6)$$

Equations (5) and (6) allow the position of the neutral axis and concrete stresses to be calculated for a given applied moment M (i.e., distance d). If the concrete modulus of elasticity can be assumed constant for the range of stresses being considered, the position of the neutral axis may be determined directly by solving Equation (6). If, however, E_c is a variable it is necessary to guess the location of the neutral axis, calculate σ_1 and check the estimate. By successive approximation, the values are determined.

APPENDIX C—STRAIN MEASUREMENTS ON STRANDS AT RELEASE OF PRESTRESS

The transfer of load from the strands to the concrete produced by releasing the strand anchorage is shown in Fig. 20. Strain gages were applied to the strands after the strand tension was developed and before placing concrete. Strains were read immediately before and after release of the strands. The strain readings shown in Fig. 20 indicate the extent of relaxation of the strands at various points along the beams. The residual prestress varies from zero at the ends of the beam to a maximum value in the middle portion of the beam determined by the elastic shortening of the concrete. It can be seen from the figure that the transfer of stress was accomplished sooner in the concrete with highest strength, and the maximum length required was about 27 in.

APPENDIX D—EFFECT OF CREEP OF CONCRETE[11]

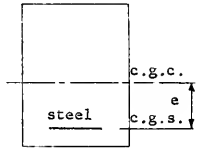
The analysis presented here is intended to show qualitatively the influence of creep of concrete upon steel stresses under repetitive loading and has been simplified (a) by neglecting any change in modulus of elasticity of the concrete while under load and (b) neglecting any shrinkage of the concrete which might occur during the loading.

The simplest problem to consider is that of loss of prestress due to creep in a beam assumed to be loaded only with a prestressing force. This problem will be discussed first followed by the analogous problem of a beam loaded by sustained load or equivalent sustained load in the case of a beam under repetitive loading.

Notation

P_i = prestressing force immediately after transfer of prestress
P_t = prestressing force at some time t after release of prestress
ΔP = change in prestressing force during time interval t

ϕ = ratio $\frac{\epsilon_t}{\epsilon_e}$
ϵ_e = elastic strain at transfer of prestress
ϵ_t = total strain at time t which consists of ϵ_e plus strain due to creep
$\frac{d\phi}{dt}$ = rate of change of strain with respect to time, i.e., rate of creep
I^c_o = moment of inertia of concrete
A_c = concrete area
E_c = modulus of elasticity for concrete
A_s = steel area
E_s = modulus of elasticity for steel



Using the diagram above, strain stiffness is defined for the steel and concrete as the force required to produce elastic unit strain in the material at the level of the steel.

For steel strain stiffness S_s,

$$\epsilon = \frac{S_s}{E_s A_s} = 1, \text{ or } S_s = E_s A_s$$

For concrete strain stiffness S_c,

$$\epsilon = \frac{S_c}{A_c E_c} + \frac{S_c e^2}{E_c I_o} = 1, \text{ or } S_c = \frac{E_c A_c}{1 + \frac{e^2 A_c}{I_o}}$$

Neglecting creep of the steel as being small compared with creep of the concrete, due to creep of the concrete the beam shortens at the level of the steel and the steel stress is decreased. With the steel bonded to the concrete, the strain in the concrete and steel at any time t must be equal. The shortening of the steel is given by:

$$\frac{d(\Delta P)}{dt} \frac{1}{S_s}$$

The shortening at the concrete consists of three parts as follows. The first part is an elastic shortening at release of prestress and being time-dependent is given by:

$$\frac{P_i}{S_c} \left(\frac{d\phi}{dt}\right)$$

The second part is an elastic shortening due to change in steel stress and being time-dependent is given by:

$$- \frac{\Delta P}{S_c} \left(\frac{d\phi}{dt}\right)$$

The third portion is due to the change in ΔP with time due to inelastic creep and is given by

$$- \frac{d(\Delta P)}{dt} \frac{1}{S_c}$$

Equating the shortening of concrete to the shortening of the steel the following equation results:

$$\frac{(P_i - \Delta P)}{S_c}\frac{d\phi}{dt} - \frac{d(\Delta P)}{dt}\frac{1}{S_c} = \frac{d(\Delta P)}{dt}\cdot\frac{1}{S_s}$$

Taking $\frac{S_s}{S_c} = \alpha$ and rearranging gives:

$$\frac{d(\Delta P)}{dt} + \alpha\frac{d(\Delta P)}{dt} - \alpha(P_i - \Delta P)\frac{d\phi}{dt} = 0$$

The solution of this differential equation is:

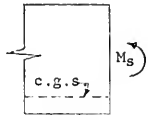
$$\Delta P = P_i\ (1 - e^{-\alpha\phi})$$

The prestressing force at time t is given by:

$$P_t = P_i - \Delta P = P_i e^{-\alpha\phi}$$

showing that the eventual prestressing force is dependent on the two quantities α and ϕ. Thus to avoid high losses of prestress, high values of α and ϕ should be avoided.

Consider now a beam loaded only with a sustained load producing stresses opposite in sign to those produced by the prestressing force.



I_o^s = moment of inertia of steel

The sustained moment M_s is carried by the concrete and steel in proportion to their relative flexural stiffnesses. Defining flexural stiffness as the moment required to produce unit angular rotation of the cross section we have for flexural stiffness of the concrete,

$$S_{cf} = I_o^c E_c$$

and flexural stiffness of the steel,

$$S_{sf} = I_o^s E_s$$

and let

$$\alpha_F = \frac{S_{sf}}{S_{cf}}$$

The moment M is carried partly by the steel and partly by the concrete.

Portion carried by steel $= M_s = M\alpha_F$

Portion carried by concrete $= M_c = M\ (1 - \alpha_F)$

Change in moment carried by the concrete (or steel) due to creep $= \Delta M_c$

Due to plastic flow of the concrete there will be a decrease in the moment carried by the concrete and an increase in the moment carried by the steel. The angular displacements must be the same for both materials.

The angular displacement in the steel is given by

$$\frac{d(\Delta M_c)}{dt}\frac{1}{S_{sf}}$$

The angular displacements of the concrete consist of three parts. The first part is due to the elastic displacement caused by M_c and is given by:

$$\frac{M_c}{S_{cf}} \frac{d\phi}{dt}$$

The second part is due to the elastic displacement caused by ΔM_c and is given by

$$\frac{\Delta M_c}{S_{cf}} \frac{d\phi}{dt}$$

The third part is due to the change in ΔM_c with time due to creep and is given by

$$\frac{d(\Delta M_c)}{dt} \frac{1}{S_{cf}}$$

Equating the angular displacements of the concrete and steel and simplifying by using $\alpha_f = \frac{S_{sf}}{S_{cf}}$, the following equation results

$$\frac{d(\Delta M_c)}{dt} + \alpha_f \frac{d(\Delta M_c)}{dt} - \alpha_f (M_c - \Delta M_c) \frac{d\phi}{dt} = 0$$

The solution being

$$\Delta M_c = M\ (1 - e^{-\alpha_f \phi})$$

where ΔM_c represents a decrease in the moment carried by the concrete and an increase in the moment carried by the steel. This increase in moment carried by the steel must result in an increase in steel stresses. The two factors ϕ and α_f again affect the change in steel stress due to creep. These are the factors which affect the error involved in calculating the fatigue strength by the theory proposed. It is known that the value of α_f is the same for the three beams tested in fatigue but that the value of ϕ will be different for the three beams. This accounts for the apparent difference in error between test results and theory for the three beams.

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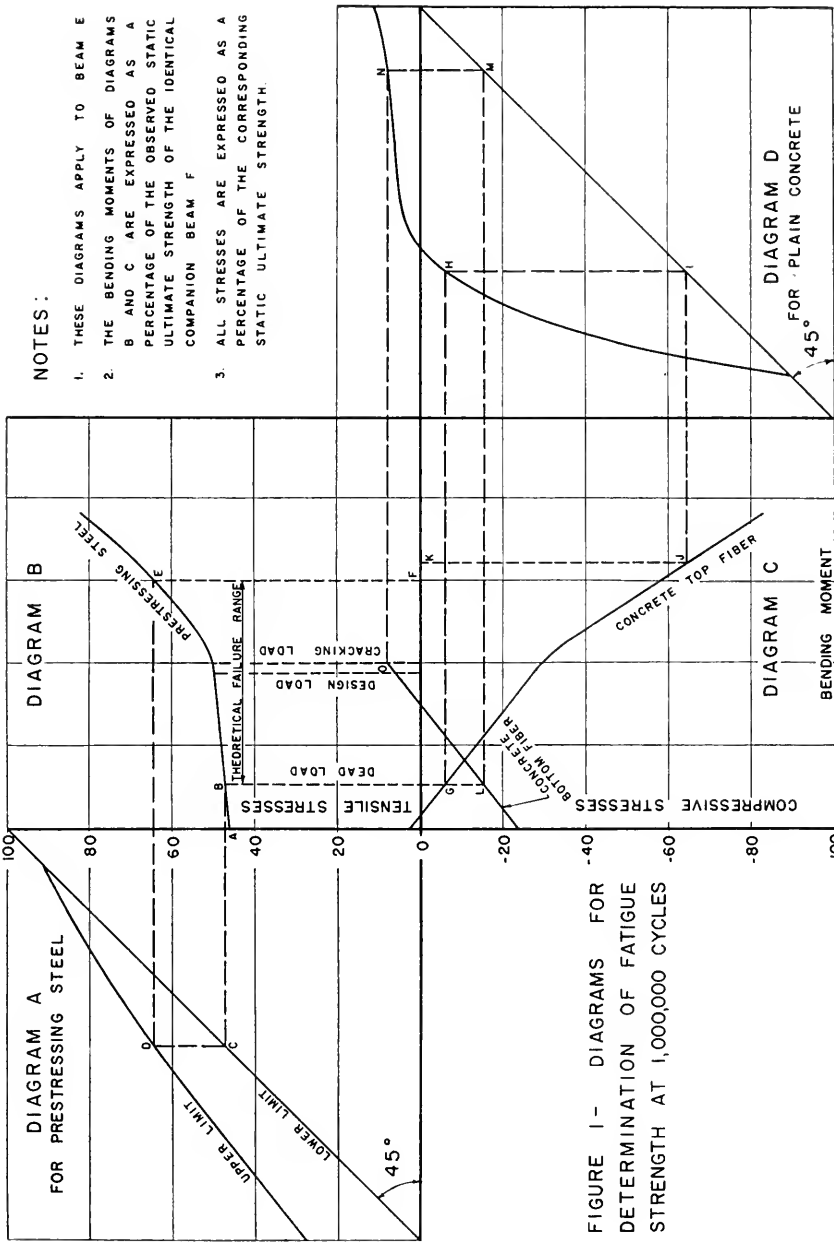


FIGURE 1- DIAGRAMS FOR DETERMINATION OF FATIGUE STRENGTH AT 1,000,000 CYCLES

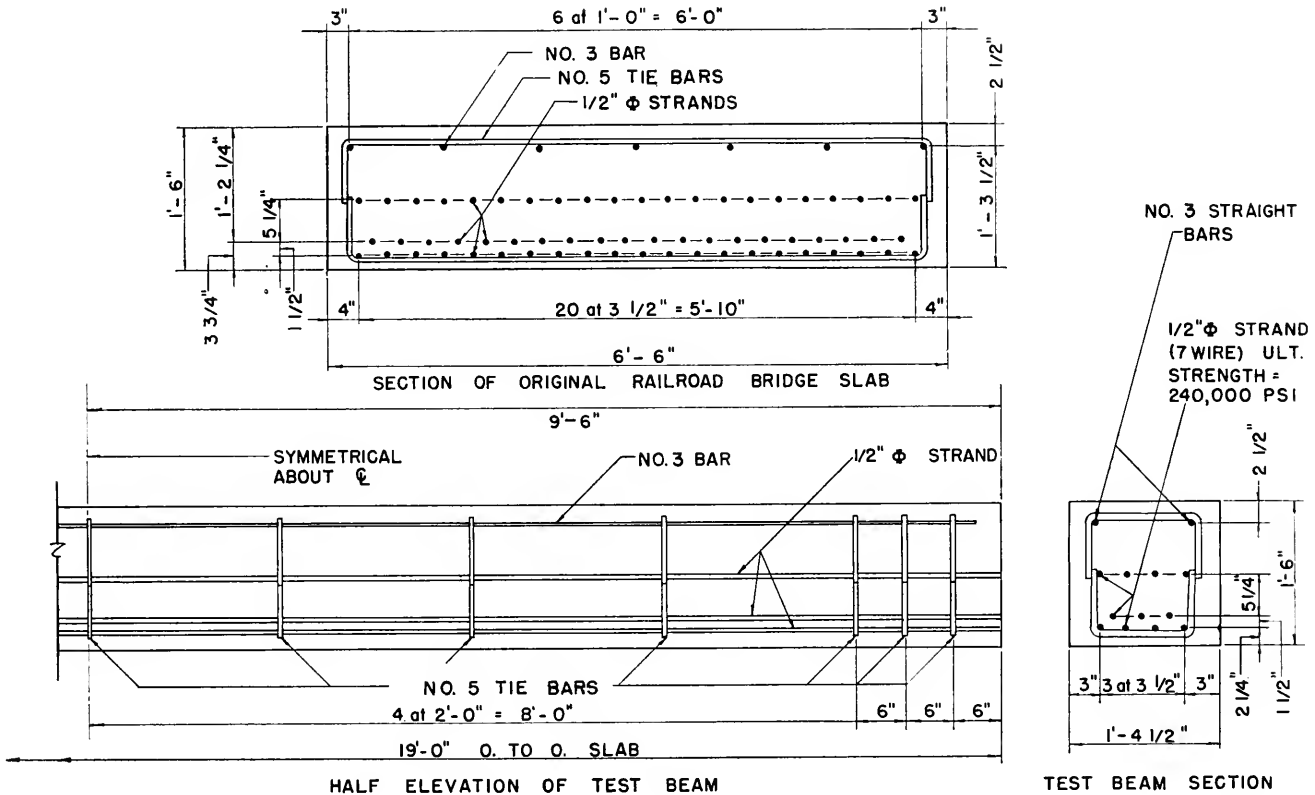


FIGURE 2 - DETAILS OF TEST BEAM AND ORIGINAL RAILROAD BRIDGE SLABS

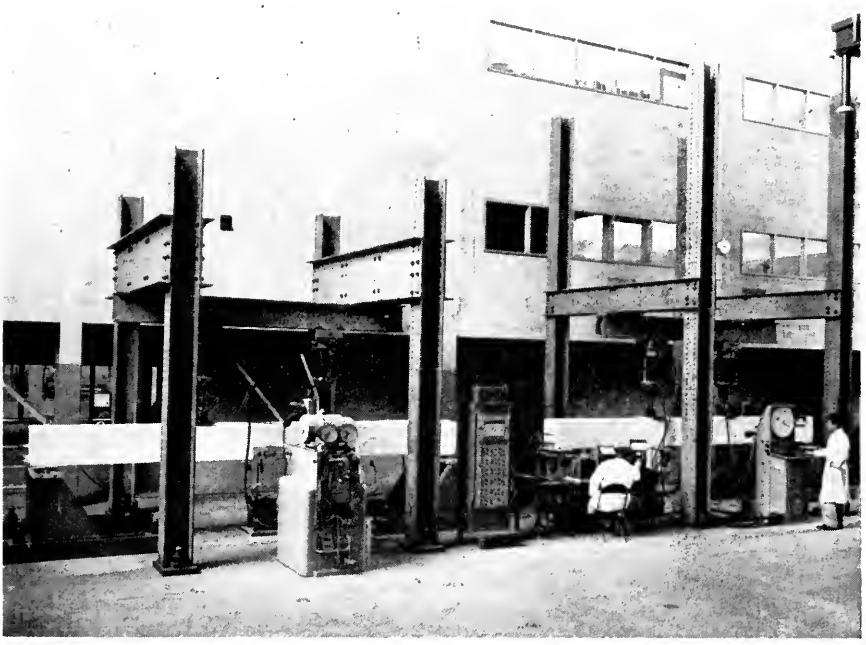


Fig. 3—View showing dynamic and static test set-ups.

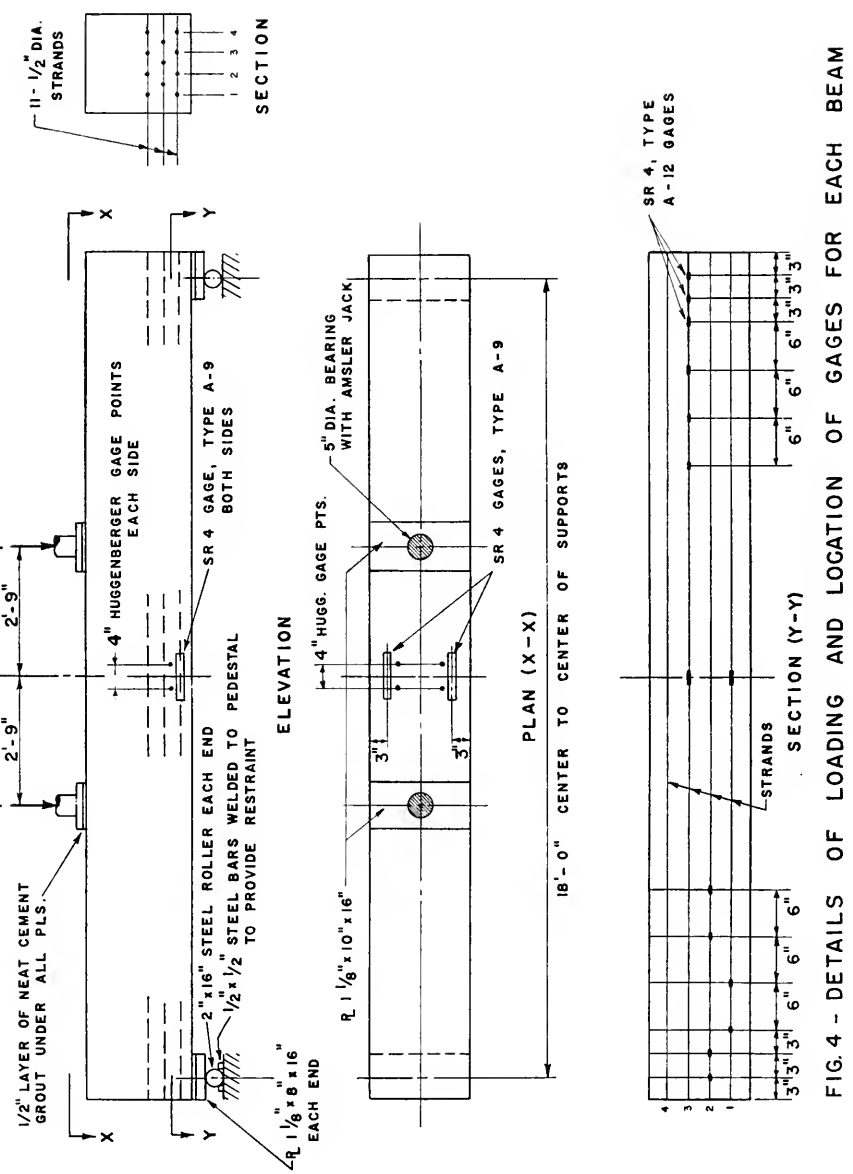


FIG. 4 - DETAILS OF LOADING AND LOCATION OF GAGES FOR EACH BEAM

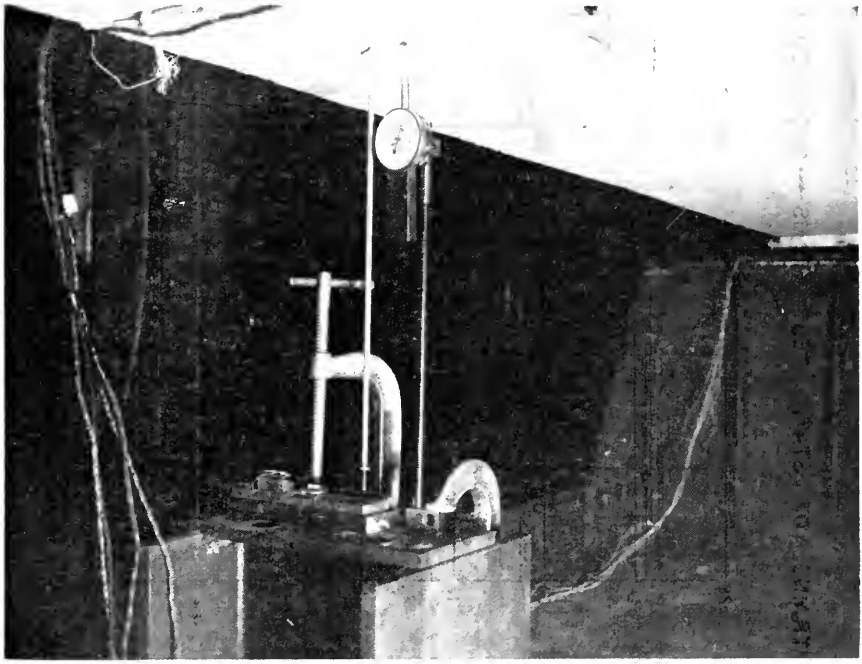


Fig. 5—View showing device for measuring dynamic deflections.

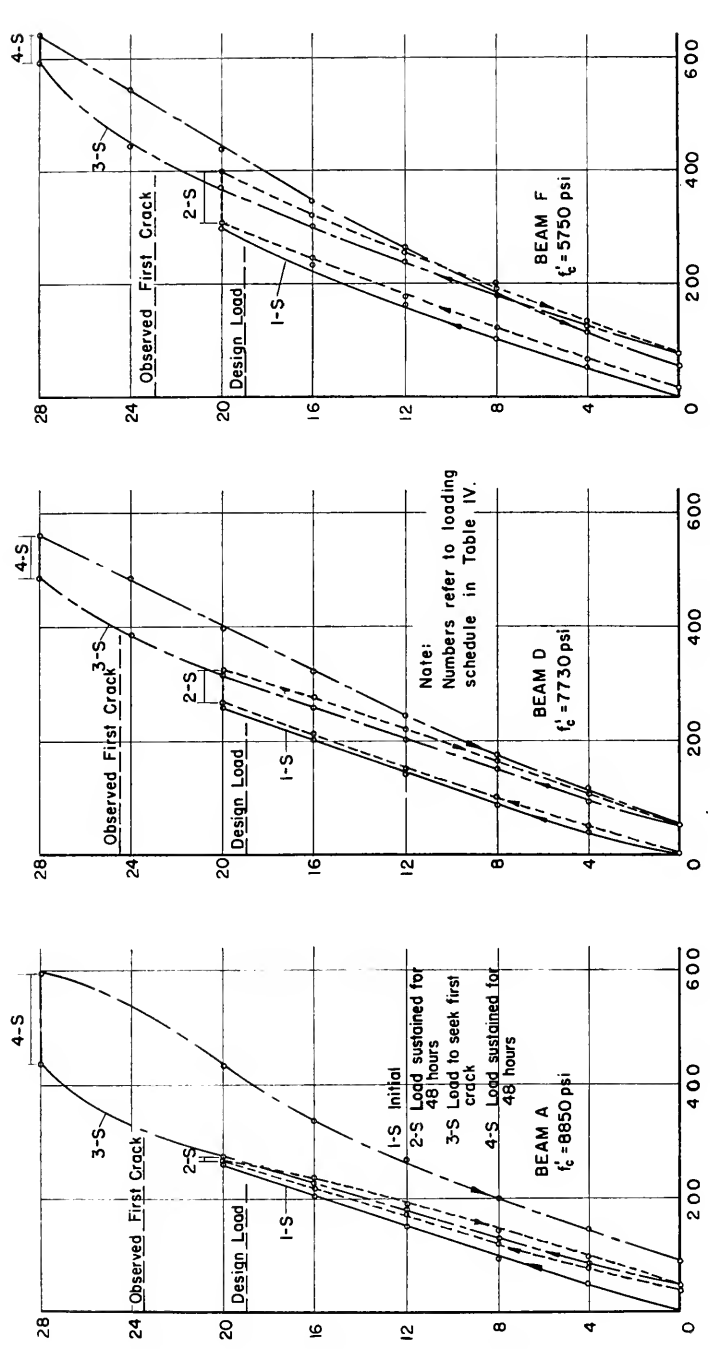


FIGURE 6- STEEL STRAINS OF STATIC TEST BEAMS — SUSTAINED LOAD TEST

FIGURE 7- CONCRETE STRAINS OF STATIC TEST BEAMS——SUSTAINED LOAD TEST

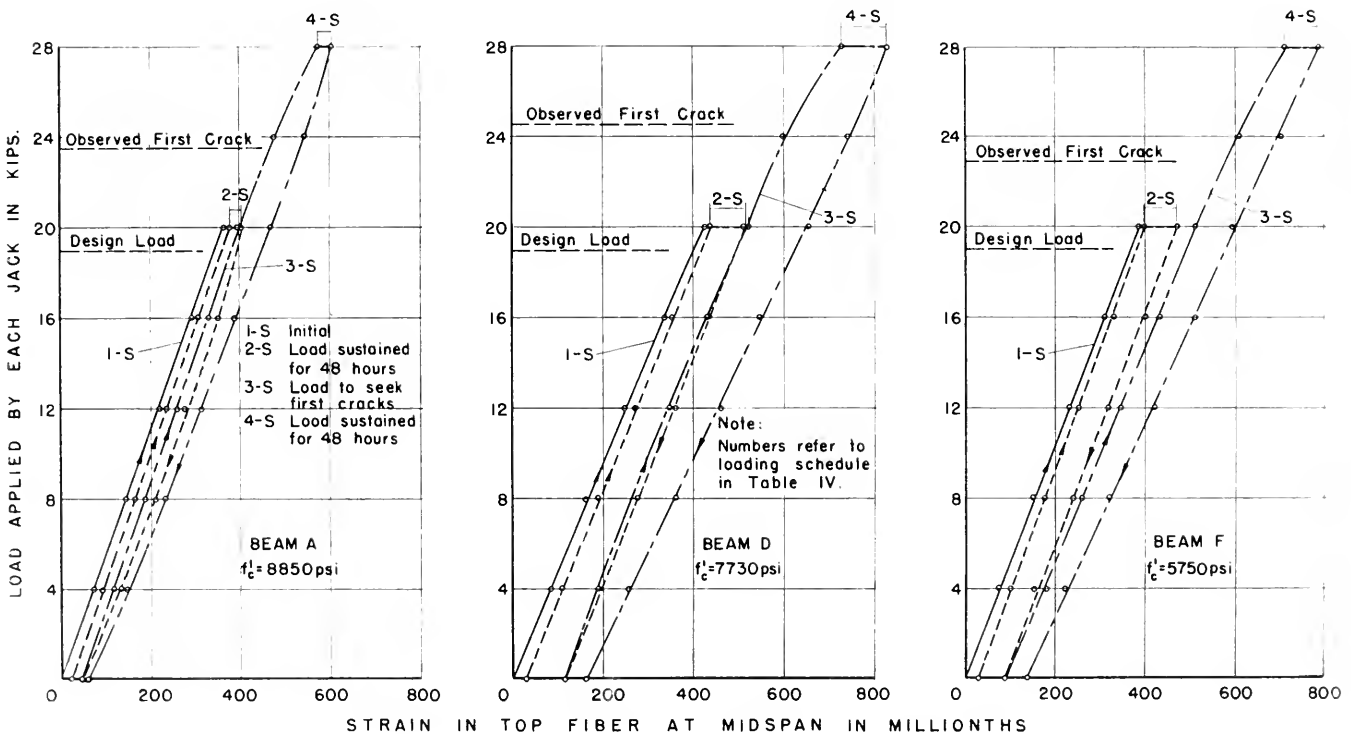
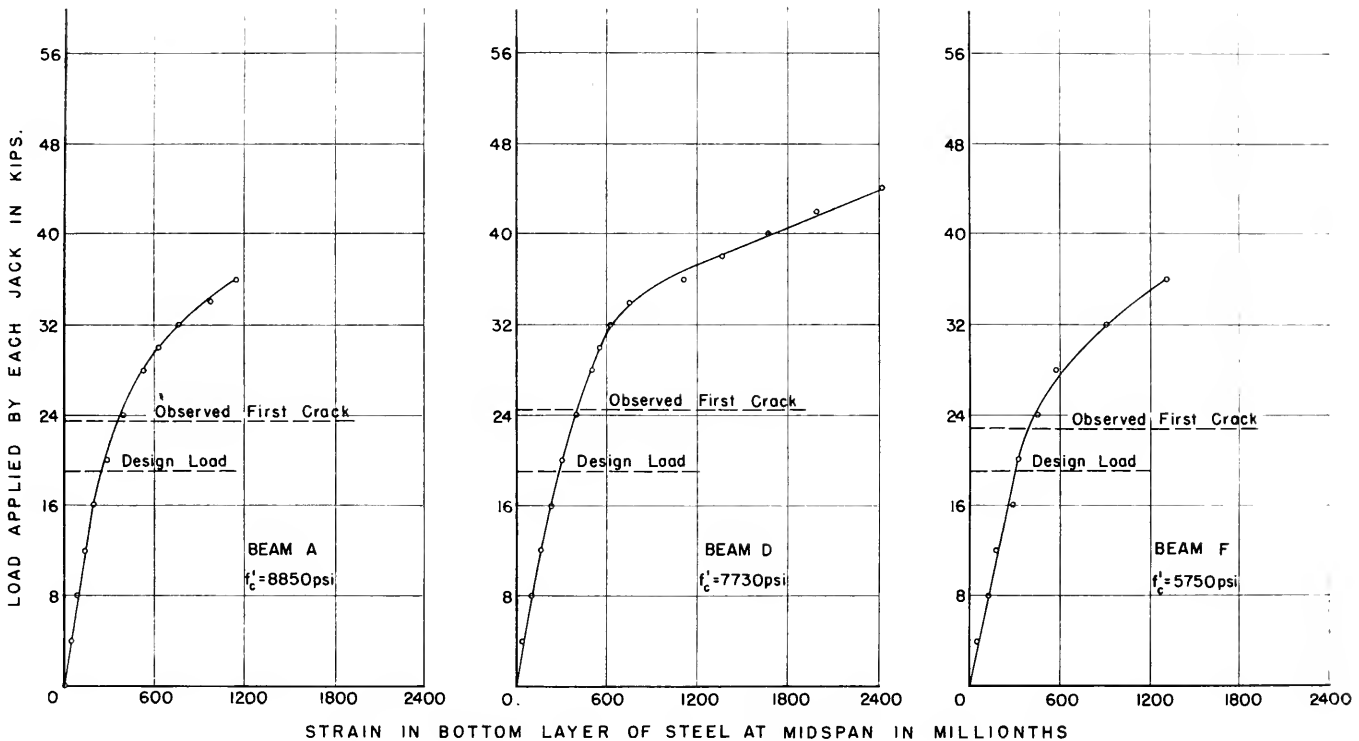


FIGURE 8- STEEL STRAINS OF STATIC TEST BEAMS — ULTIMATE LOAD TEST



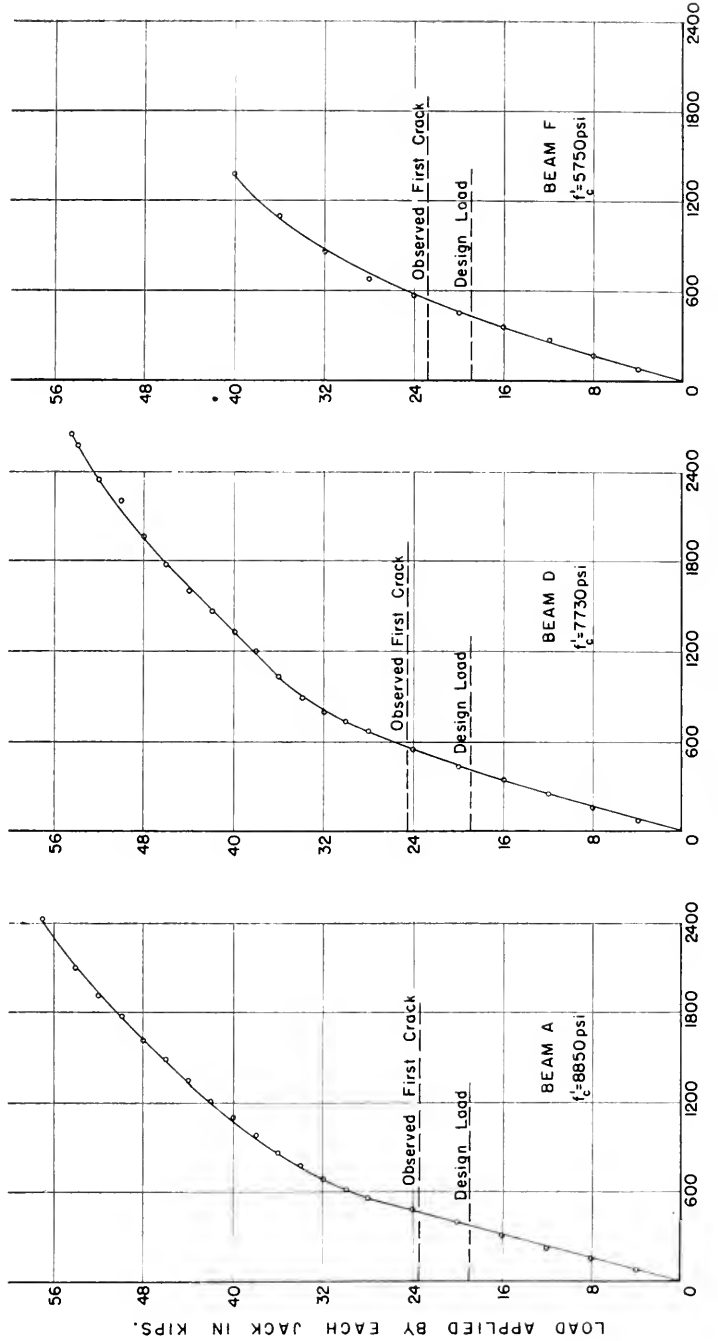


FIGURE 9- CONCRETE STRAINS OF STATIC TEST BEAMS — ULTIMATE LOAD TEST

FIGURE 10 - CONCRETE STRAINS OF FATIGUE TEST BEAMS

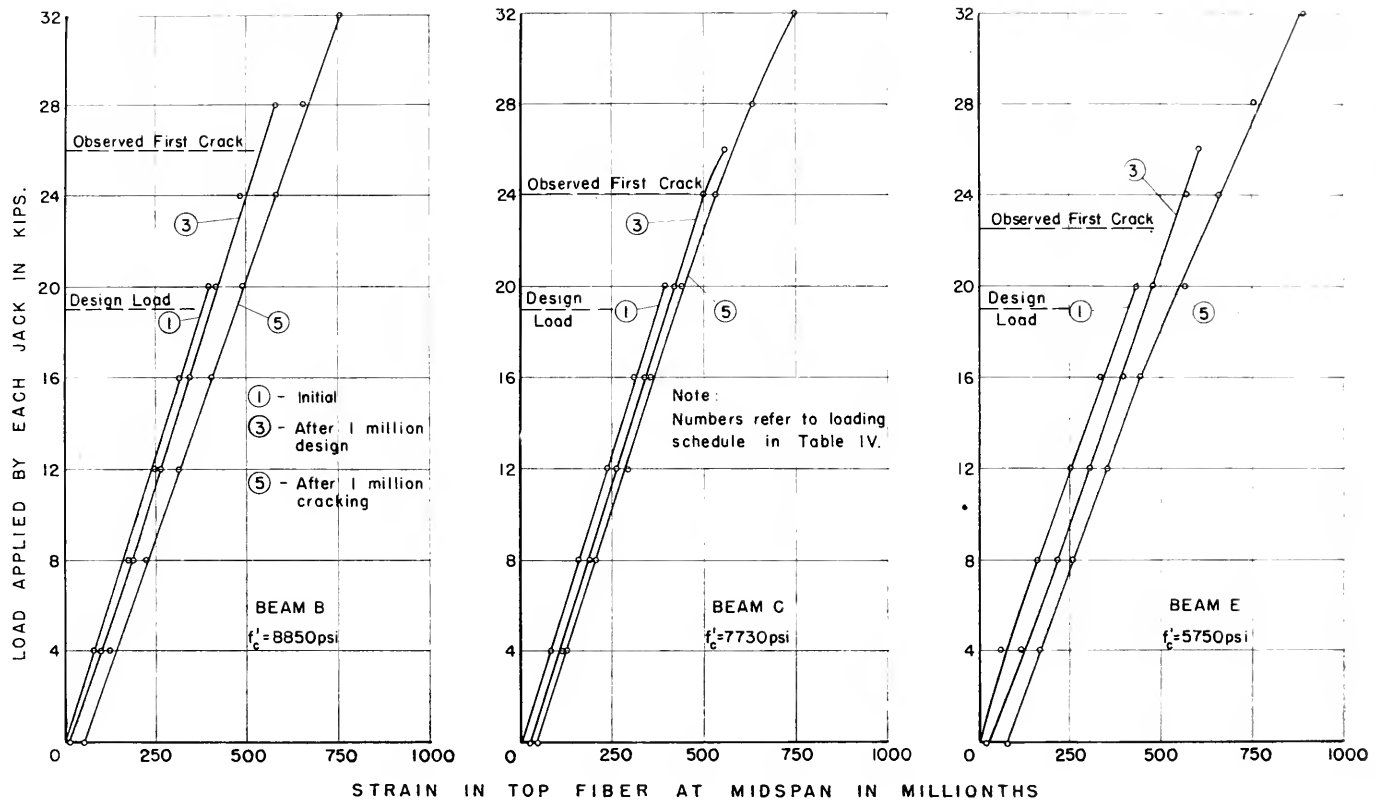


FIGURE 11 - DEFLECTION OF STATIC TEST BEAMS — SUSTAINED LOAD TESTS

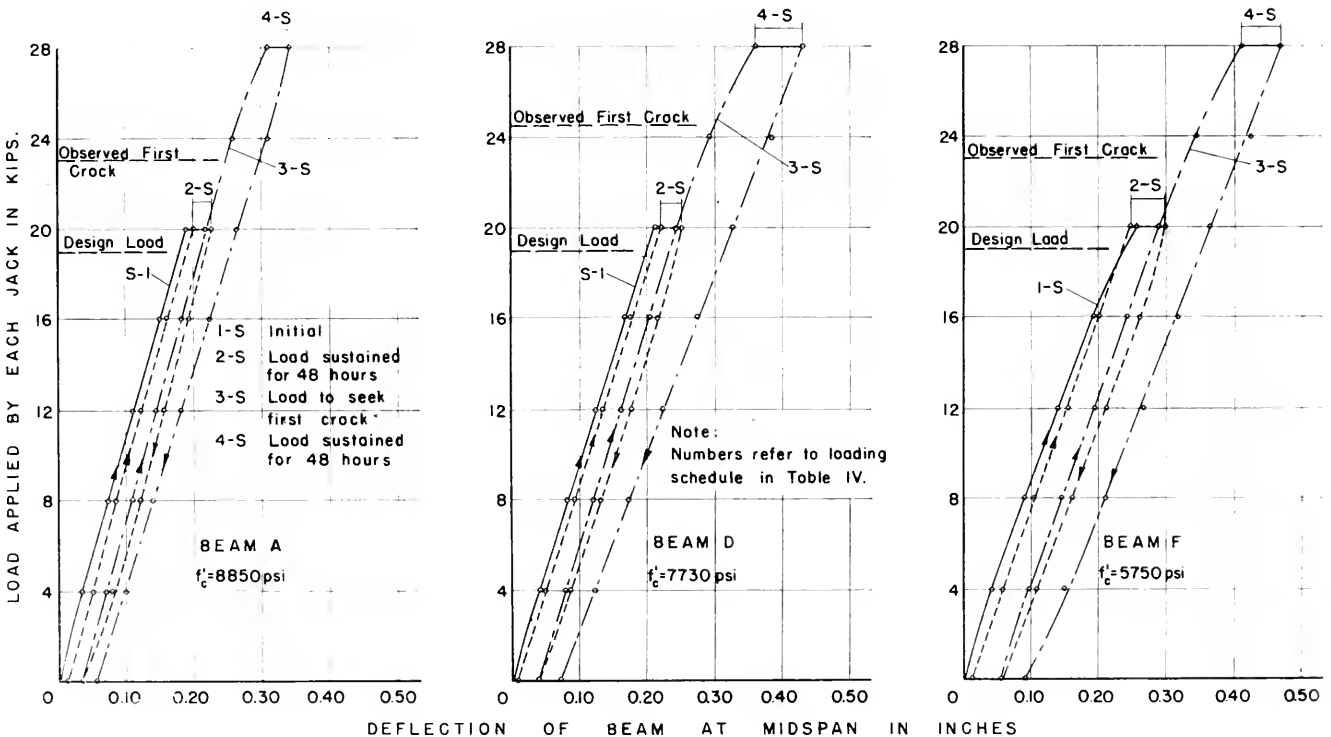


FIGURE 12 – DEFLECTION OF STATIC TEST BEAMS — ULTIMATE LOAD TEST

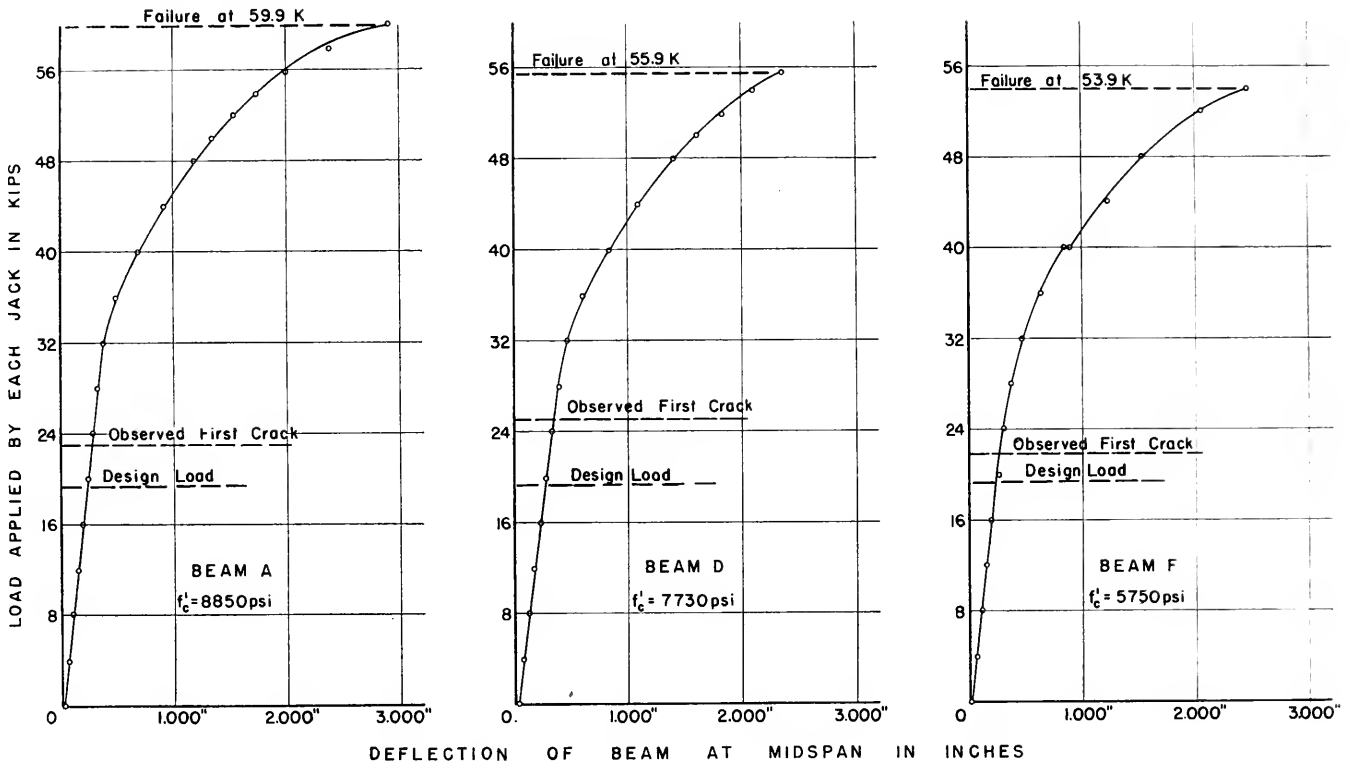
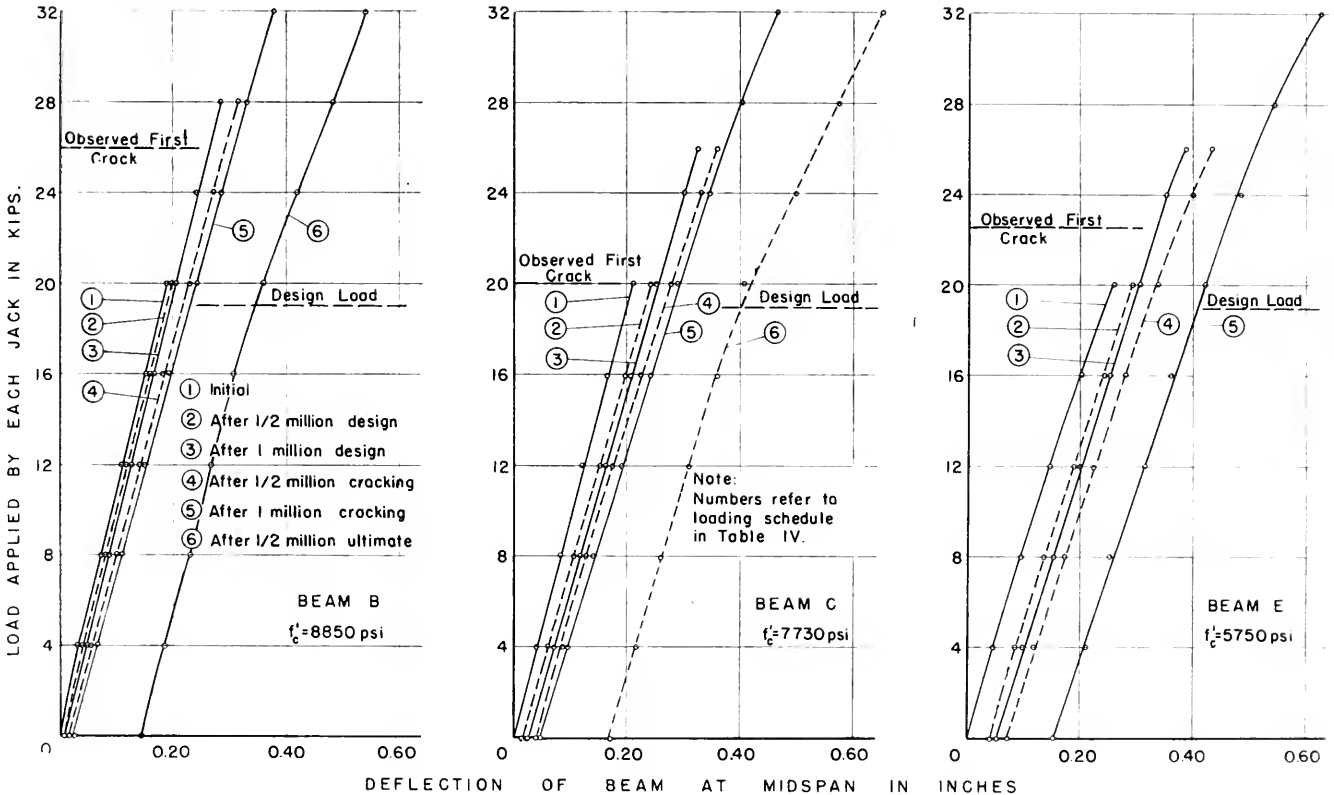
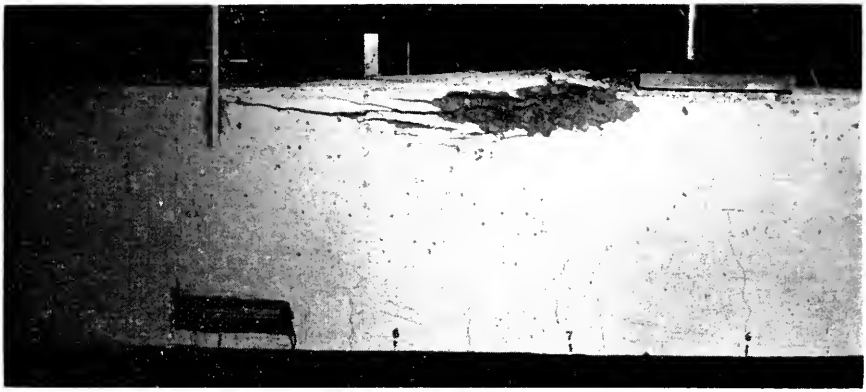


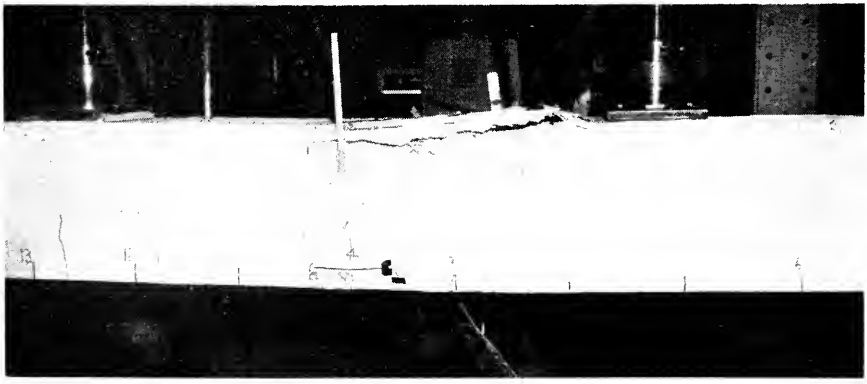
FIGURE 13 - DEFLECTION OF FATIGUE TEST BEAMS — STATIC TESTS





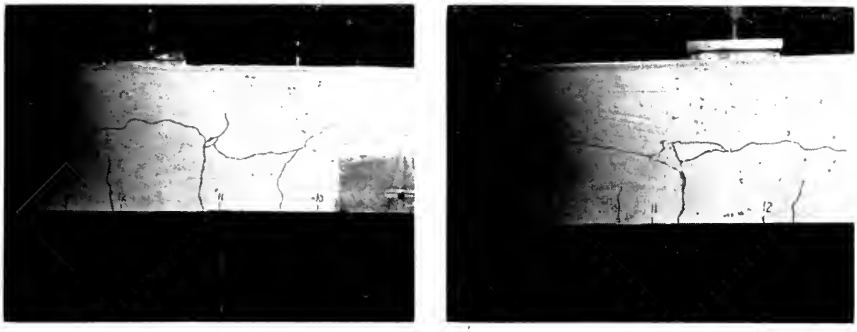
Beam A

Beam D

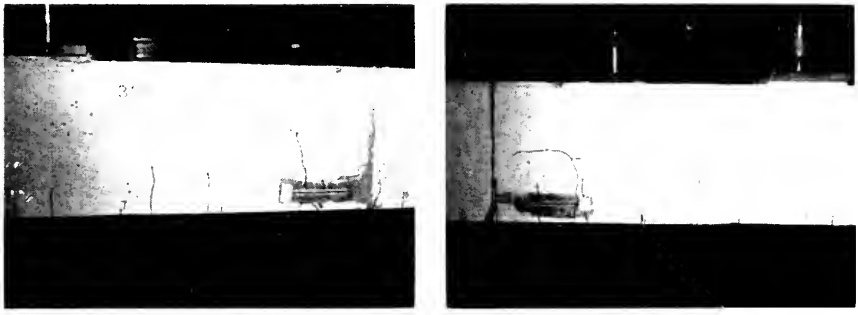


Beam F

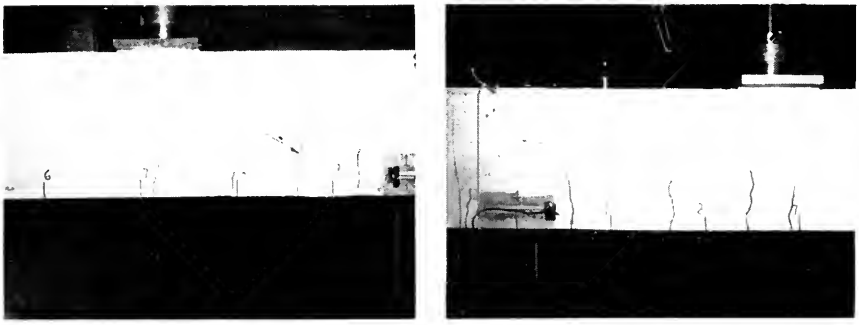
Fig. 14—Views showing static test beams after failure.



Beam B

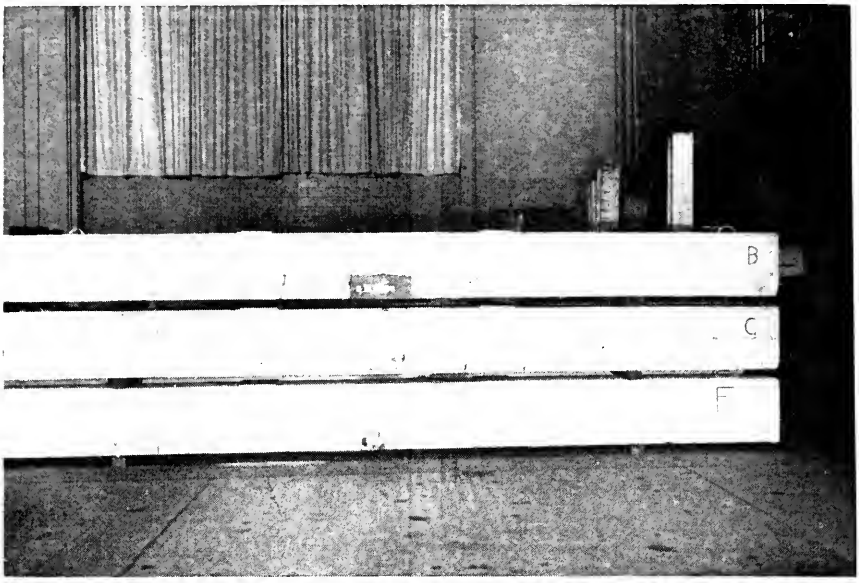


Beam C

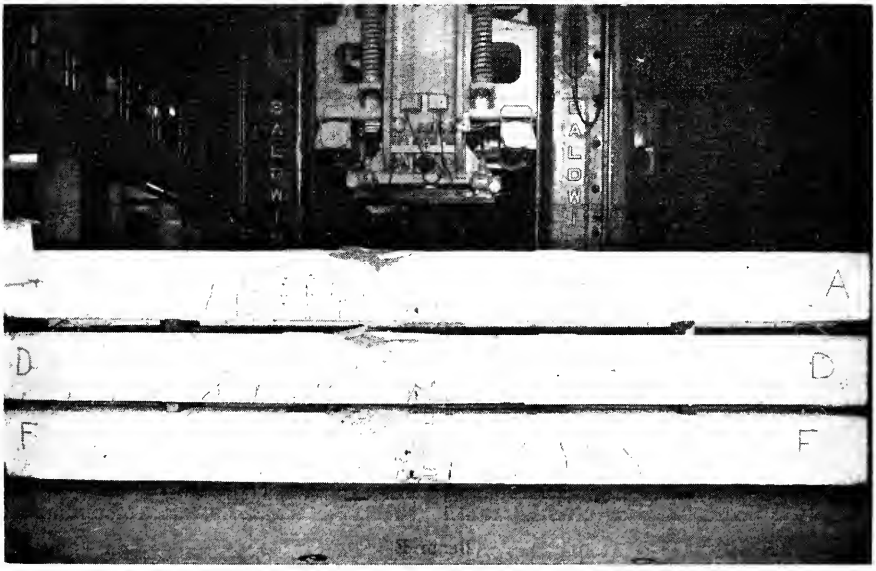


Beam E

Fig. 15—Views showing dynamic test beams at failure load (Run 3-D). The south sides of the beams are shown at the left, north sides at the right.



Dynamic test beams



Static test beams

Fig. 16—Views showing test beams after failure.

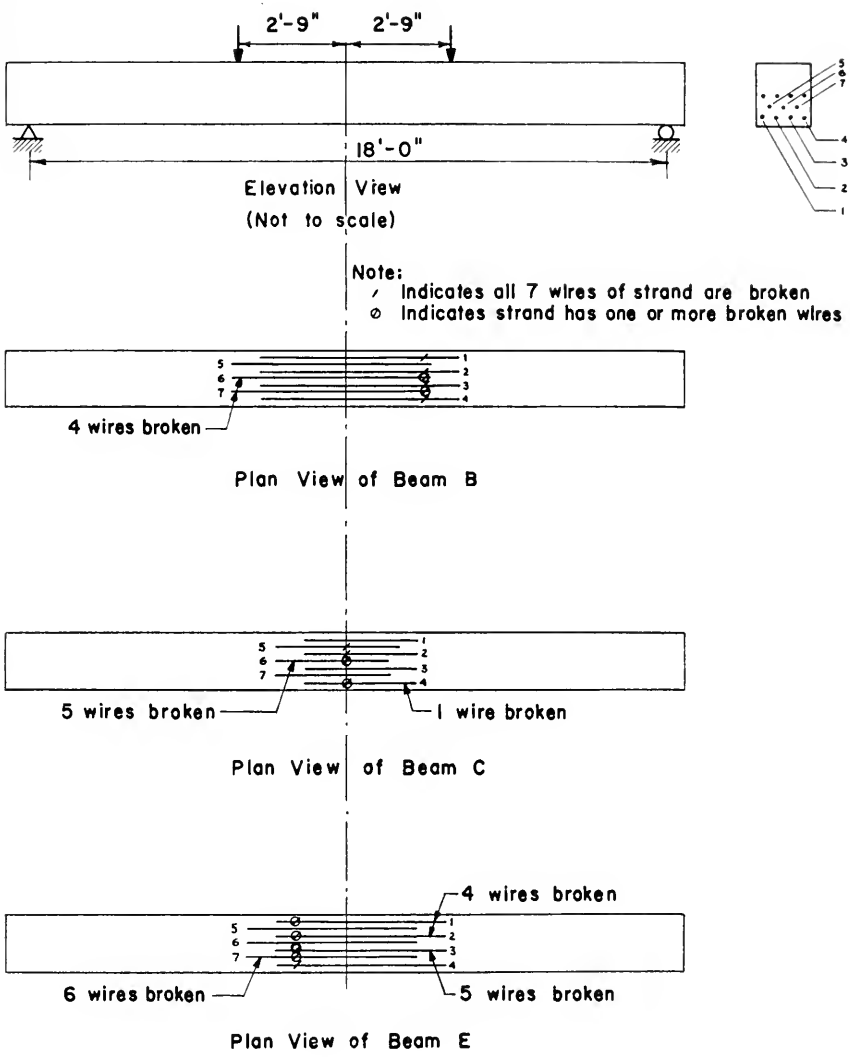


FIGURE 17 - DIAGRAMS SHOWING LOCATION OF DAMAGED STRANDS

Fig. 18—View of beam B showing strand fractures.

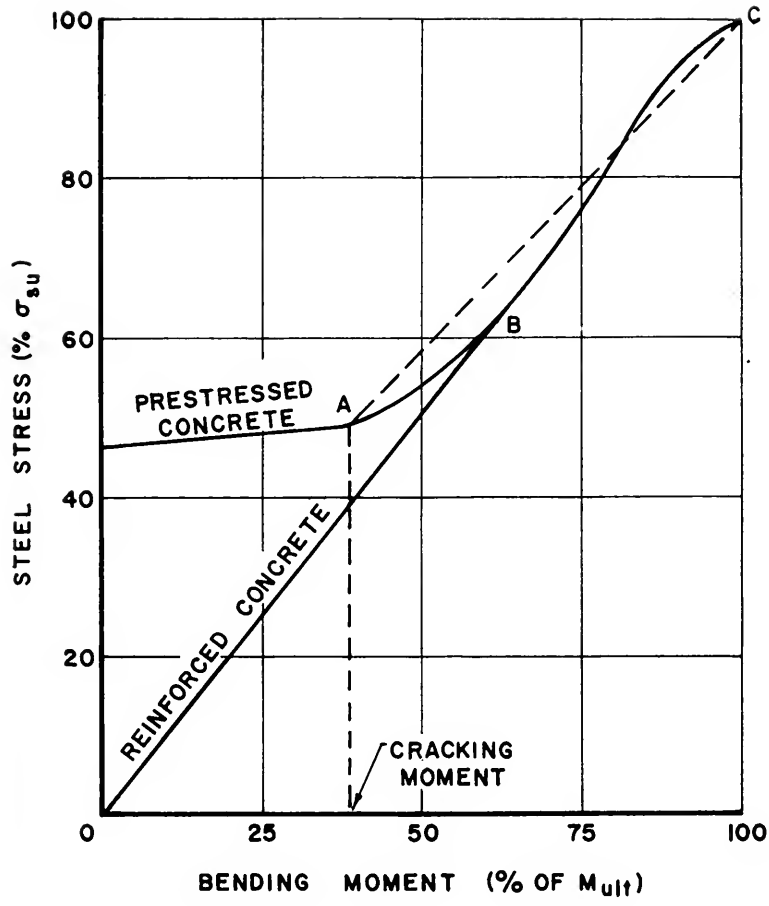


FIG. 19 — TYPICAL STEEL STRESS vs. MOMENT DIAGRAMS

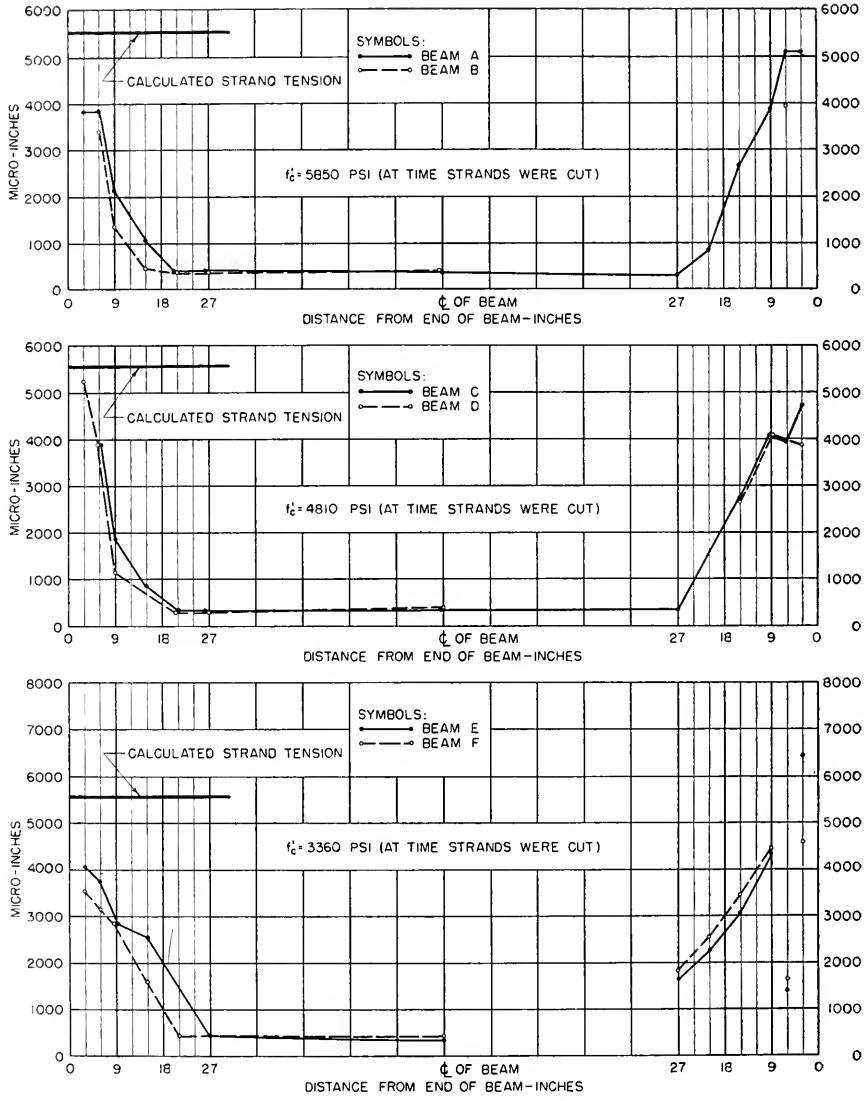


FIG. 20 - TRANSFER OF STRAND TENSION TO CONCRETE WHEN STRANDS WERE CUT

Testing the Genesee & Wyoming's York Viaduct with the AAR Research Center's Mobile Laboratory.

Advance Report of Committee 30—Impact and Bridge Stresses

D. S. Bechly, *Chairman*

Tests of a Steel Viaduct on the Genesee & Wyoming Railroad

A. DIGEST

This is a report on field tests of the York viaduct of the Genesee & Wyoming Railroad, near Retsof, N. Y.—a 478 ft long structure consisting of 13 deck girder spans supported on steel towers. Strain gages were applied to various elements of the viaduct, as follows:

Top and bottom flanges of girders at center of span.
Columns near the bases.
Tower bracing.
Running rails.

A test train was used to determine the maximum stresses and total impacts for a complete range of speeds from 5 to 33 mph. Longitudinal forces were developed by the test train braking on the structure and accelerating off it, and the resulting stresses in the tower bracing and in the running rails were measured.

Salt corrosion has caused considerable loss of flange material, and the girders were strengthened by welding additional angles to the flanges between stiffeners. The effectiveness of this added material was determined.

The results of this test may be summarized as follows:

1. The static stresses in the top flanges of all the girders tested were higher than in the bottom flanges, probably because of the greater corrosion of the top flange. The maximum average recorded static stress was 6.20 ksi.

2. The recorded average static stresses in the top flanges of the girders were as much as 17 percent higher than the calculated stresses based on full section, but the bottom flange stresses were lower.

3. All recorded maximum live-load-plus-impact stresses in the girder flanges were less than the calculated stresses.

4. Recorded static stresses across a column section varied from zero to 7.56 ksi. Local effects probably caused this large variation.

5. The recorded average static stresses in the columns were higher than the calculated stresses by as much as 44 percent.

6. The average recorded maximum live-load-plus-impact stresses in the columns exceeded the calculated stresses in several instances.

7. All recorded total impacts in the girders and the columns were less than the current AREA allowance for rolling equipment without hammer blow.

8. The material which was added to the flanges is effectively strengthening the girders.

9. Braking of the trains produced longitudinal force of 17.58 kips in the bracing between bents 2 and 3 and 17.78 kips in the rails.

10. The direct load of the train on the tower caused a higher stress in the tower bracing than the braking of the train. This maximum stress was 3.74 ksi.

11. The tractive force applied by the test locomotive caused negligible stress in the tower bracing and running rails.

B. FOREWORD

At the request of the Genesee & Wyoming Railroad the AAR research staff conducted tests and secured data on various elements of this road's York Viaduct. The tests were conducted during July and August, 1956, and a full report of the results was furnished to the railroad company in December of that year.

Since the assignments of Committee 30 include studies of stresses and impacts in steel girder spans, permission was granted by the railroad company to publish the results of this test as a committee report.

The York Viaduct, built in 1900, consists of a series of 13 deck girder spans on steel towers for a total length of 478 ft, as shown on Fig. 1. It is located on the main line of the Genesee & Wyoming near Retsof, N. Y. Since most of the tonnage carried by this railroad is rock salt from a nearby salt mine, this structure is subjected to severe salt corrosion. The girder section has been considerably reduced by this corrosion, and to strengthen it in 1947 the top and bottom flange areas were increased as shown on Figs. 2 and 6. Thus, one of the reasons for conducting this test was to determine the effectiveness of this added material in carrying live load. The structure has an open timber floor with a single tangent track. The railroad operates only diesel locomotives and furnished a special test train to secure the data comprising this report.

This test was carried out under the general direction of G. M. Magee, director of

engineering research, Engineering Division, AAR. All of the direct costs involved in the test were borne by the Genesee & Wyoming.

The conduct of the test, analysis of the data and preparation of the report were under the direction of E. J. Ruble, research engineer structures, assisted in the office and field by F. P. Drew, assistant research engineer structures, and W. J. Murphy, former assistant research engineer structures. This report was prepared by Mr. Drew.

C. INSTRUMENTS

Since the structure was accessible by truck, the Research Center's mobile laboratory was used (see photograph, page 51). The instruments used in this test consist essentially of two 12-channel oscillographs, which recorded the strains on photographic paper in response to the SR–4 wire resistance gages cemented on the bridge at various points. A description of the SR–4 gages and the necessary recording equipment is given in the AREA Proceedings, Vol. 52, 1951, page 152. The relative position of each locomotive and car wheel with respect to the structure was indicated by two solenoid marker units in each oscillograph which were connected to spring-type switches located on the rail at the center line of spans 2 and 4. The speed of each locomotive was readily obtained from the oscillograms by determining the elapsed time for the locomotive to pass between these wheel position markers. Two additional spring-type switches were located on the rail at a spacing of one-fortieth of a mile and connected to an electric timer which automatically recorded the elapsed time for each locomotive to cover this distance.

Each strain gage circuit was calibrated individually before each test run, and a calibration check was made at the completion of each run. All the gages mounted on the girders and towers were calibrated for a sensitivity of 1 in trace deflection equal to 10.000 psi in the member, assuming a modulus of elasticity of 30.000,000 psi.

D. TEST SPANS AND LOCATION OF GAGES

As shown on Fig. 1, spans 2, 3 and 4 were used as test spans. The girders are spaced 8 ft 0 in on centers. Spans 2 and 4 are identical in span length and composition. The girders of spans 2 and 4 are 43 ft 11 in over-all and 43 ft 3 in center to center of bearings, while those of span 3 are 27 ft 11 in over-all and 27 ft 3 in center to center of bearings. The top flanges are braced by a single lateral system, and there are end and intermediate crossframes.

The open timber floor consists of 8-in by 12-in by 10-ft ties spaced 16 in on centers. The center line of track is 1⅛ in west of the center line between girders at the center of span 2, 1⅞ in west at span 3 and 1 in west at span 4. The west girders, therefore, are calculated to carry 51.2, 52.0, and 51.0 percent, respectively, of the total live load. The capacity of the spans in flexure, using the full gross section plus reinforcement and present AREA design stresses and impact for diesel locomotives, is E 96 for spans 2 and 4 and E 80 for span 3.

The girders were strengthened by welding two 3½- by 3½- by ½-in angles to each flange, as shown on Fig. 6. The angles were cut and fitted between the stiffeners. The toes of the angles were welded to the original flange angles, and the ends of the angles were welded to the stiffeners.

Strain gages were applied to the top and bottom flanges of each girder near the center line of the spans 2, 3 and 4. In addition to these gages placed at the extreme fiber, gages were applied to the east girder only near the center line of span 4 to deter-

mine the longitudinal distribution of strains along the strengthening angles and the original flange material. These gages were applied midway between the stiffeners and at the ends of the strengthening angles as close to the stiffeners as possible.

The ends of each girder span bear on steel bents. Except at the ends of the viaduct, the bents are spaced 28 ft and 44 ft on centers. Those at 28 ft comprise the towers which have single or double cross bracing as the height increases. The columns of each bent are battered and consist of a web plate and four Z sections.

Strain gages were applied at the four corners of the columns near the base and to the tower bracing angles.

To measure the amount of longitudinal force transmitted to the rails, strain gages were applied to the neutral axis of the 80-lb rail at the north end of the viaduct and 330 ft from the north end on span 10.

The location of all gages is shown on Fig. 2.

E. TEST TRAINS

Except for a few runs obtained under regular trains the entire test was conducted with a special test train consisting of a diesel locomotive and six cars. The locomotive weight was 240,000 lb, and each car weighed 169,000 lb, as shown on Fig. 1.

The rating of this test train on the 27-ft 11-in span was E 33.8 and on the 43-ft 11-in span, E 35.5.

The test train was operated at various speeds from about 5 mph (which was considered the same as static loading) to a maximum of 33 mph. In addition to these runs, which were used to determine the dynamic effect, several runs were made with the train coming to an abrupt stop (under a service application of the brakes) near the north end of the viaduct. Several runs were also made with the locomotive accelerating off of the viaduct from various points.

F. ANALYSIS OF FIELD RECORDS

The oscillograms obtained during this test are similar to those obtained from previously reported tests. A total of 77 runs were recorded on the two oscillographs, producing 154 oscillograms which form the permanent record of strains at the various gage locations under the passage of the live loads. In all cases the recorded stresses represent only the live-load stress, to which must be added a dead-load stress to obtain the total stress. The gages were applied to the gross section of the members between the rivet holes or other stress raisers.

1. Static Stresses

The recorded stresses in the flanges of the girders and the columns were determined from the maximum mean stresses secured under the slow speed runs of approximately 5 mph of the test train. The calculated static stresses were based on concentrated wheel loads and the gross section of the members. The exact position of the train to produce the maximum recorded static stress was secured from the oscillograms. It was noted that the maximum recorded static stress did not occur solely from the loading of the locomotive, but that the heavily loaded cars also produced maximum stress. Thus, the maximum recorded stress in spans 2 and 4 occurred when the trailing truck of the locomotive and the lead truck of the first car were on the span. The maximum stress in span 3 occurred when the two adjacent trucks of the first and second cars were on the spans. Similarly, for the north columns of tower 1, the maximum stress occurred

when the adjacent trucks of the locomotive and the first car straddled the columns, and for the south columns when the adjacent trucks of the first and second cars straddled the columns.

a. Top and Bottom Flange Near Center of Girder

A comparison of the recorded and calculated static live-load stresses and the resulting stress factors is shown in the following tabulation. The stress factor is the ratio of the recorded to the calculated stresses.

	Average Recorded Static Stress			*Calculated Static Stress*	*Stress Factor Rec./Cal.*
	E. Girder	*W. Girder*	*Average*		
Span 2—Top Flange	−6.20	−5.10	−5.65	−4.83	1.17
Span 2—Bottom Flange	+4.05	+3.98	+4.02	+4.83	0.83
Span 3—Top Flange	−3.29	−2.48	−2.88	−4.14	0.70
Span 3—Bottom Flange	+2.01	+2.16	+2.08	+4.14	0.50
Span 4—Top Flange	−5.39	−5.42	−5.40	−4.65	1.16
Span 4—Bottom Flange	+3.34	+3.00	+3.17	+4.65	0.68

It can be seen from the above tabulation that the top-flange stresses were higher than the bottom-flange stresses. This is probably due to the loss of top flange material from corrosion with a consequent lowering of the neutral axis. It can be seen further that the top-flange stresses of span 2 and 3 were highest on the east girder. It was noted previously that the track was slightly off-center, putting more load on the west girders; apparently the corrosion was enough more severe on the east girders to offset this eccentricity of the track.

It is also noted from the stress factors that the top-flange recorded stresses were higher than the calculated stresses whereas the opposite was true on the bottom flange. Undoubedly the corrosion of the top flange caused this, since the calculated stresses were based on the top flange having its full section.

b. Columns Near the Base

A comparison of the recorded and calculated static live-load stresses and the resulting stress factors is shown in the following tabulation for the columns of tower 1.

	Recorded Static Stress		*Calculated*	*Stress Factor Rec./Calc.*
	Maximum	*Average*		
Northeast Column	−7.80	−5.30	−3.68	1.44
Northwest Column	−5.80	−4.48	−3.68	1.22
Southeast Column	−7.21	−3.98	−3.41	1.17
Southwest Column	−7.56	−3.49	−3.41	1.02

It is noted from the above tabulation that the stress factors are all greater than unity, indicating high recorded stresses compared to the calculated. These stress factors are based on the average stress as recorded simultaneously on four gages at the edges of the column section near the base. There was a large variation between the stresses as recorded on the individual gages. For example, during one run the four gages on the northeast column recorded the following stresses:

−4.21 ksi
−7.80 ksi
−7.11 ksi
−3.39 ksi

and during that same run the southwest column gages recorded these stresses:

−5.61 ksi
−7.56 ksi
0 ksi
−0.71 ksi

Hence, it is apparent that there were factors present to create high corner stresses. Bending of the column about the base, concentrated bearing pressure near one edge and the secondary effect of the gusseted connection of the tower bracing could all contribute to these high corner stresses. Since there was this large variation, the average recorded stress probably does not represent the true recorded direct stress, consequently the stress factors are high.

Nevertheless, the fact that the average stresses were higher for the north columns than for the south columns does indicate there has been some differential settlement to transfer additional load to the north columns.

2. Maximum Stresses

The maximum live-load-plus-impact stresses recorded in the top and bottom flanges and in the columns at a full range of speeds to 33 mph are shown on Figs. 3, 4 and 5. Also shown on these diagrams are the calculated stresses based on the current AREA design specification impact allowance for rolling equipment without hammer blow.

a. Top Flange Near Center of Girder

An examination of Fig. 3 reveals that there was no significant increase in maximum stress with an increase in speed. In fact, in several instances the maximum stress was actually reduced with an increase in speed. The maximum recorded stress was 7.18 ksi in the top flange of the east girder in span 2.

While the recorded static stress exceeded the calculated stresses on spans 2 and 4, none of the recorded maximum stresses exceeded the calculated values. On span 3 all recorded stresses were less than the calculated stresses.

It was noted previously that the static stresses were highest in the top flanges of the east girders in spans 2 and 3, and this same trend was apparent for stresses at the higher speeds also.

b. Bottom Flange Near Center of Girder

The diagrams at the top of Fig. 4 indicate that all recorded stresses were less than the calculated stresses, with no significant increase in stress with an increase in speed.

It is also apparent from these diagrams that the variation in bottom-flange stress between the east and west girders is relatively small. There was not the loss of flange material at the bottom that there was at the top to affect the stress variation.

c. Columns Near the Base

As was the case with the girder flanges, the top diagrams of Fig. 5 show no significant increase in maximum stress with an increase in speed. The maximum recorded stress at one corner of a column was 8.35 ksi, and the maximum average stress was 6.00 ksi, as shown.

The calculated maximum stress in the north columns of tower 1 is 5.47 ksi, and it can be seen from the upper right diagram that several average recorded maximum stresses exceeded this value. This is not surprising, as the average recorded static values were nearly this high, and a large variation of stress occurred between the four corner gages at maximum stress.

The calculated maximum stress in the south columns of tower 1 is 5.08 ksi, and the upper left diagram indicates that all average recorded maximum stresses were less than this. There were individual corner stresses which did exceed this calculated value, however.

3. Total Impacts

The total impacts recorded in the bottom flanges of the girders near center of span and in the columns near the base are shown in the lower diagrams of Figs. 4 and 5. The total impact percentage for a particular speed is the increase in stress in the member over the average stress occurring at slow speed. The total impacts include the combinations of (1) speed effect, (2) roll effort and (3) track effect, but these various effects were not separated for this analysis.

a. Bottom Flange Near Center of Girder

It can be seen from the diagram that there was an increase in impact with an increase in speed on the 27-ft 11-in span, but such a relationship is not so apparent on the 43-ft 11-in span. In all cases, however, the recorded impact was less than the AREA design specification allowance for rolling equipment without hammer blow. The maximum impact recorded was 38.4 percent on the 27-ft 11-in span. The AREA design allowance for this span is 51.0 percent. The recorded impacts were generally higher for the shorter span. Since all the spans are the same depth, the indication is that the increased stiffness of the short span was a factor causing higher impacts in this span.

b. Columns Near the Base

The plotted values of recorded impacts indicate that all values are less than those calculated according to the AREA design specifications. The maximum impact recorded was 36.1 percent in the southeast column of tower 1; the calculated value is 41.9 percent.

4. Distribution of Bottom Flange Stress

To determine the longitudinal and vertical distribution of stress over the bottom flange, particularly to determine the effectiveness of the strengthening material, strain gages were applied to the east girder of span 4 as shown on Fig. 6.

The "Location of Sections" indicates that gages were applied to the strengthening angles and to the original flange angles and plates. A set of such gages was applied midway between stiffener angles at Section D–D, a similar set applied at the ends of the strengthening angles at Section N–N and another similar set applied at the ends of the strengthening angles at Section P–P in the adjacent stiffener panel.

The graphs on this figure show the average recorded static and dynamic stress variation along each gage line at the various sections. It can be seen from these graphs that the stresses were highest along gage lines "g" and lower along gage lines "a" and "d" as the neutral axis was approached. It is also noted that along all gage lines (except line "g") that there was a slight decrease in stress between Sections D–D and P–P, due probably to the reduction of moment between these two points. The fact that the change in stress occurred in the original flange material as well as in the added strength-

ening material indicates that the welds at the ends of the angles were transferring stress to the outstanding leg of the stiffener and then to the angles in the next panel and, therefore, were effective in strengthening the girder.

5. Braking and Traction Stresses

A tabulation of the recorded stresses in the tower bracing and in the rails resulting from the test train braking on the structure is shown on Fig. 7.

For the braking runs the train approached the structure at a speed of about 15 mph, and when the locomotive reached the south end a service application of the brakes was made and held until the train came to an abrupt stop. The highest braking stresses were obtained when this abrupt stop was made with the lead wheels of the locomotive near the north rail gages. The column at the extreme right of the tabulation indicates the position of the lead wheel of the locomotive after stopping.

The recorded rail stresses in kips are shown for the rail gage locations, and it can be seen that during these braking runs the rails ahead of the locomotive were stressed in compression and those behind in tension. The maximum simultaneous stresses recorded were 0.69 ksi compression and 0.44 ksi tension in the 80-lb rails. The longitudinal force to produce these stresses was, then, 17.78 kips.

Simultaneous stresses were also recorded in the tower bracing, as indicated by the location of bracing gages on Fig. 7. There does not seem to be any definite pattern as to the magnitude of the stress in relation to the location of the train. It is noted, however, that the kind of stress is consistent for all braking runs ,and that in any panel of cross bracing each of the braces carries stress of opposite sign which is consistent with the applied longitudinal force. The simultaneous recorded stresses in the bracing of bents 2 and 3 were 1.70 ksi compression and 1.14 ksi tension which are the average of the stresses in the braces on the east and west sides of the tower. The longitudinal force to produce these stresses is 17.58 kips. This is equivalent to 6.4 percent of the girder reaction on the bents.

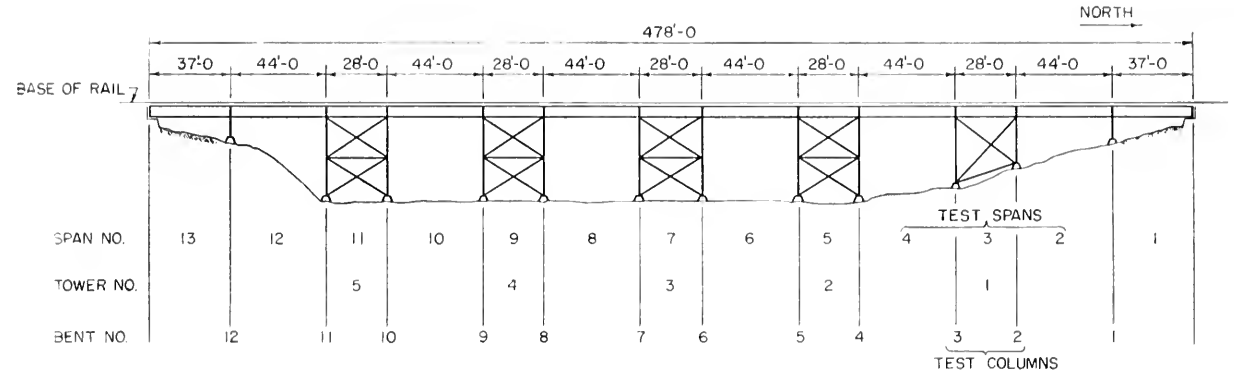
Stresses in the bracing were also recorded under the direct load of the test train, and it will be noted that for each run the maximum stress in the bracing occurred under this direct load rather than under the braking load. The maximum direct stress in the bracing was 3.74 ksi and occurred during run 59 when the train came to a hard stop with the locomotive directly over the tower with that bracing.

It is interesting to note that these stresses were not all compressive as might be expected. In tower 1 the brace leading to the base of the south column carried a tensile stress under direct load, whereas the other brace carried a compressive stress. It will be noted on Fig. 5 that the column stresses were higher in the north columns than in the south columns. It seems likely that part of the load to the south column is being transferred to the north column through the tower bracing.

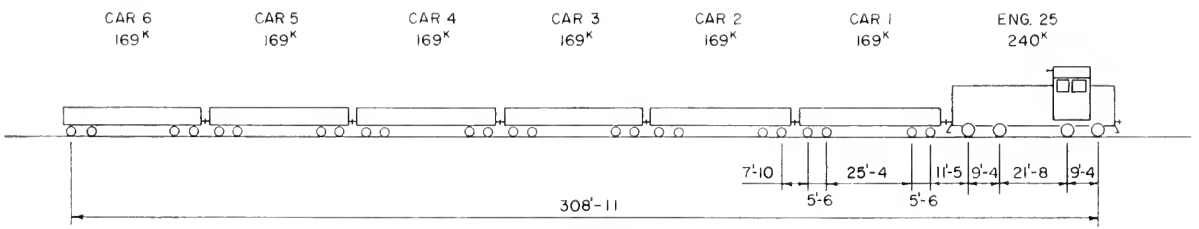
The effect on the rails and the structure of a train accelerating off the structure was also determined. The engine was positioned in two different locations from which the run started: (1) over tower 2, and (2) just south of the south backwall. No perceptible stress was recorded for either position.

G. CONCLUSIONS

The test showed that the material added to the flanges effectively strengthens the girder.

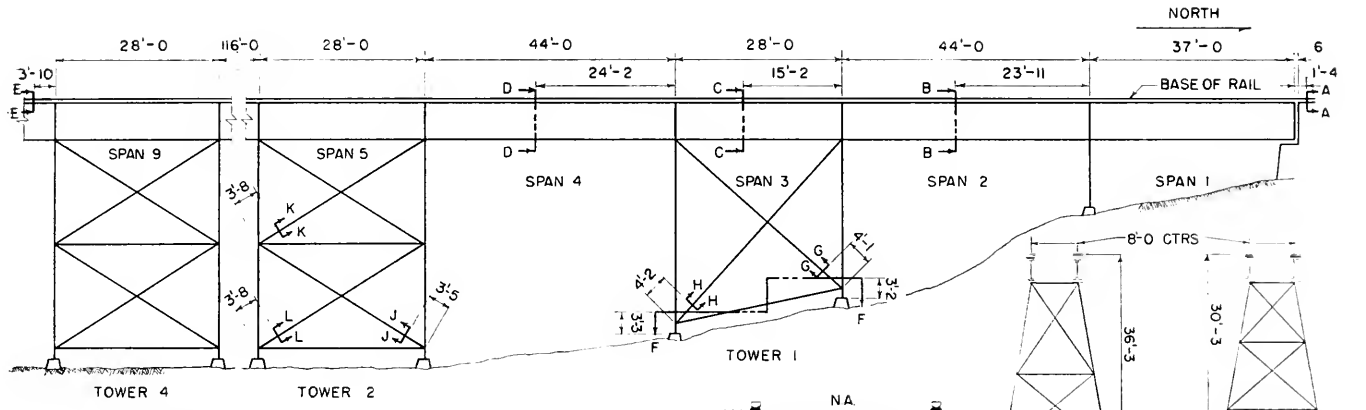


ELEVATION OF VIADUCT



TEST TRAIN

FIG. 1
GENESEE & WYOMING RR BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR
LOCATION OF TEST SPANS

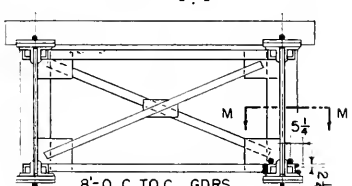


N.A.

SEC. A-A & E-E

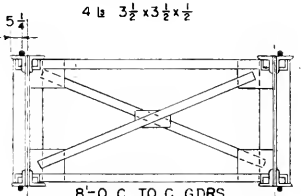
GIRDER SECTION
1 WEB 54 x 3/8
4 ls 6 x 6 x 1/2
4 COV. PLS 14 x 7/16
4 ls 3 1/2 x 3 1/2 x 1/2

WEST EAST

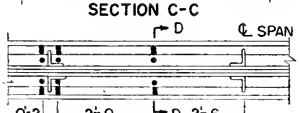


SECTION B-B & D-D

GIRDER SECTION
1 WEB 54 x 5/16
4 ls 6 x 4 x 9/16
4 ls 3 1/2 x 3 1/2 x 1/2

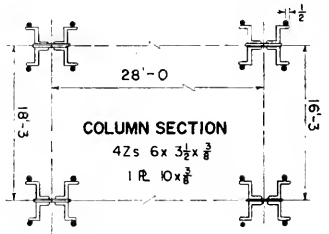


SECTION C-C



SECTION M-M

NOTE:
SECTION BB DOES NOT HAVE GAGES ON ANGLES
• INDCATES POSITION OF SR4 WIRE STRAIN GAGES



SECTION F-F

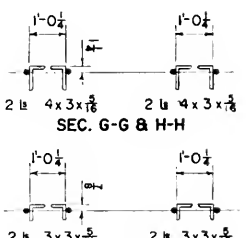


FIG. 2
GENESEE & WYOMING R.R. BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR
LOCATION OF GAGES

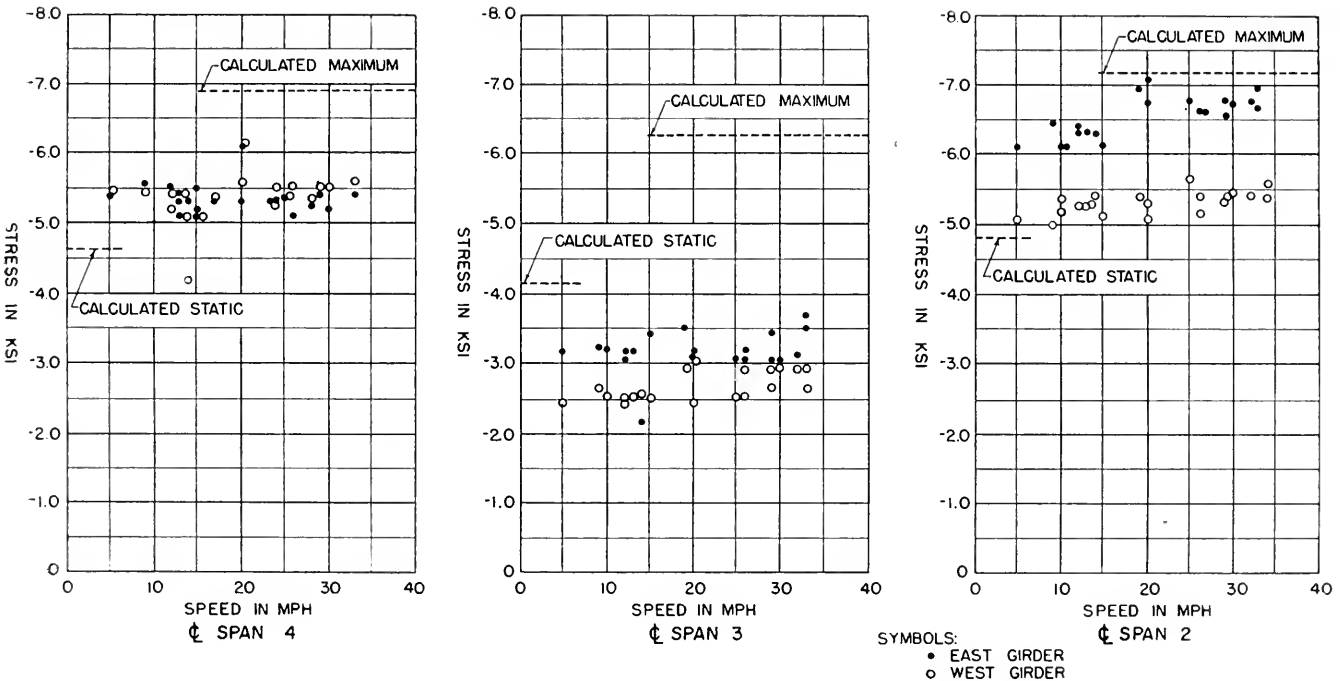


FIG. 3
GENESEE & WYOMING RR BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR
MAXIMUM STRESSES
TOP FLANGE AT CENTER OF SPAN

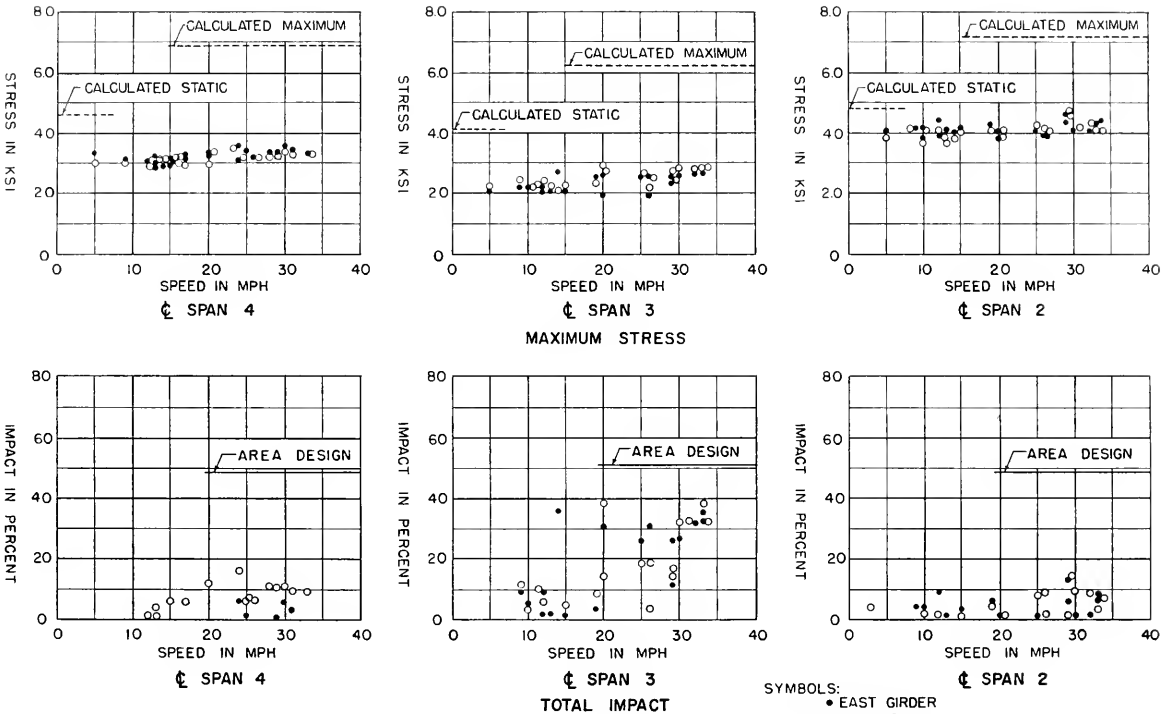
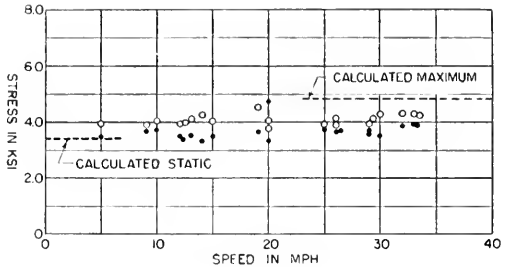
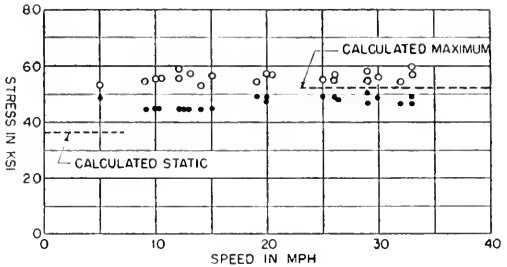


FIG. 4
GENESEE & WYOMING RR BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR

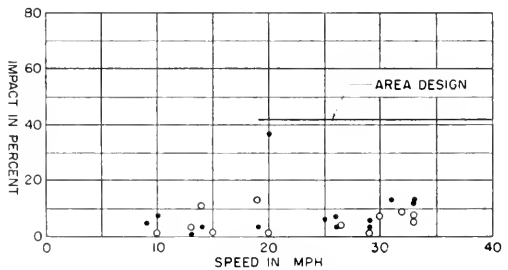
MAXIMUM STRESS AND TOTAL IMPACT

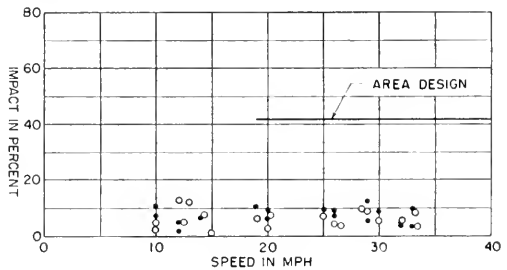
BOTTOM FLANGE AT CENTER OF SPAN



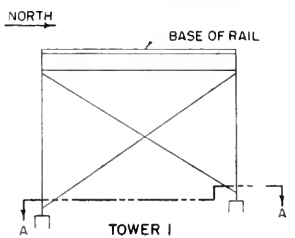


MAXIMUM STRESS





TOTAL IMPACT



SYMBOL:
• EAST COLUMN
o WEST COLUMN

FIG. 5
GENESEE & WYOMING RR BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR

MAXIMUM STRESS AND TOTAL IMPACT
COLUMNS OF TOWER I

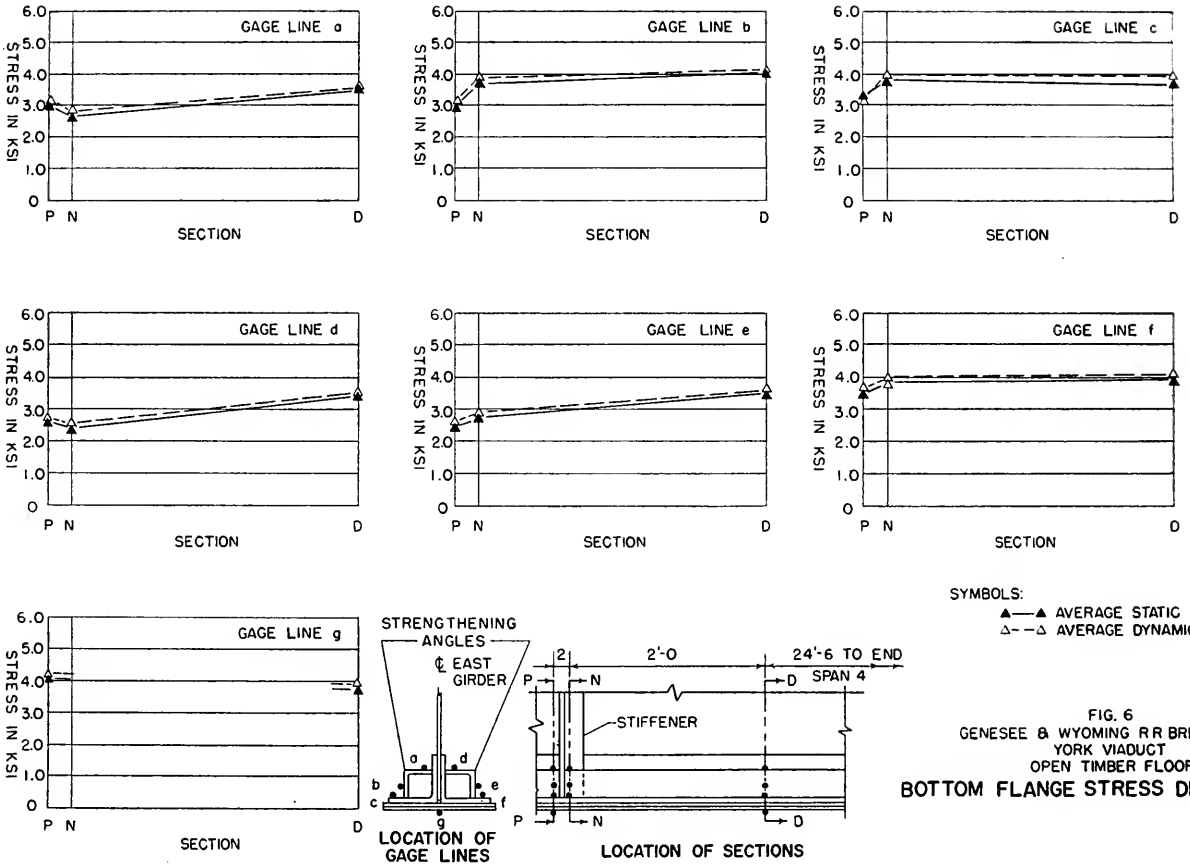
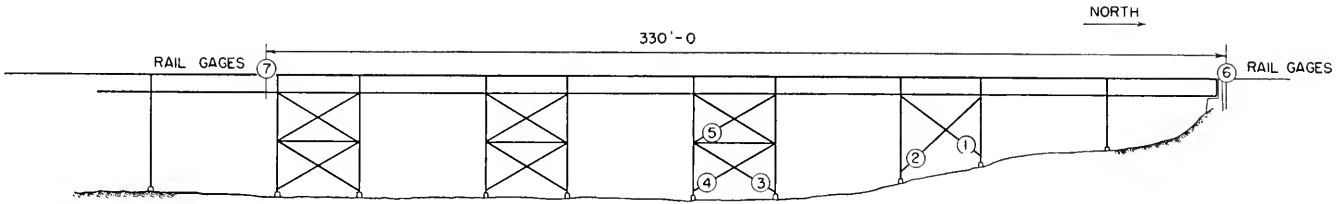


FIG. 6
GENESEE & WYOMING R R BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR
BOTTOM FLANGE STRESS DISTRIBUTION



RUN NO	STRESS FROM VERTICAL LOAD					STRESS FROM BRAKING							DIST. FT
	①	②	③	④	⑤	①	②	③	④	⑤	⑥	⑦	
59	-3.74	+2.56	-2.48	+1.88	+1.72	-1.39	+1.07	-1.65	+1.20	+1.05	-0.42	+0.30	+92
61	-3.20	+2.02	-2.35	+1.75	+1.57	-1.43	+1.15	-1.05	+1.15	+0.87	-0.52	+0.39	-2
62	-3.00	+1.94	-2.52	+1.72	+1.62	-1.51	+1.15	+1.20	+1.10	+0.97	——	+0.39	-1
63	-2.83	+1.85	-2.63	+1.67	+1.57	-1.70	+1.14	-1.30	+1.15	+1.05	-0.69	+0.44	+14
64	-2.86	+2.24	-2.30	+1.92	+1.80	-0.99	+0.69	-0.80	+0.80	+0.67	-0.41	0	+21
66	-2.46	+2.27	-2.40	+1.62	+1.45	-1.40	+1.11	-1.10	+1.12	+0.97	-0.67	+0.35	+2
67	-2.76	+1.77	-2.35	+1.77	+1.70	-1.15	+0.68	-0.85	+0.80	+0.77	-0.27	+0.31	+14
68	-2.68	+2.09	-2.12	+1.57	+1.37	-1.58	+1.10	-1.15	+1.20	+1.00	-0.68	+0.40	+6
70	-2.72	+1.86	-2.60	+1.55	+1.50	-0.90	+0.66	-0.85	+0.80	+0.65	-0.39	+0.23	+16

NOTE:

BRACING STRESSES IN KSI, AVERAGE EAST AND WEST BRACES
RAIL STRESSES IN KSI, AVERAGE FOR TWO RAILS
DIST = DISTANCE TRAIN STOPPED FROM NORTH RAIL GAGES
+ = DISTANCE TO FIRST WHEEL SOUTH OF RAIL GAGES
- = DISTANCE TO FIRST WHEEL NORTH OF RAIL GAGES

FIG. 7
GENESEE & WYOMING RR BRIDGE TEST
YORK VIADUCT
OPEN TIMBER FLOOR
BRAKING STRESS

Advance Report of Committee 15—Iron and Steel Structures

D. V. Messman, *Chairman*

Cumulative Damage in Structural Joints

By W. H. Munse,[1] James R. Fuller[2] and Kenneth S. Petersen[3]

A. SYNOPSIS

The applicability of laboratory fatigue tests of structural joints to actual structures has long been questioned by the research engineer as well as the field engineer because the studies in the laboratory are generally made under conditions in which the maximum and minimum stresses remain constant during an entire test. In actual structures, however, the stress cycles are seldom of constant magnitude and may vary from cycle to cycle in a random manner. Thus, constant cycle laboratory fatigue tests provide only relative data on the fatigue lives of service structures or their components.

To determine the fatigue lives of members which are subjected to variable cycles of loading requires that tests be made with cyclic stresses of the same frequency and magnitude as the actual service stresses, or that an adequate hypothesis be available to explain the behavior of such members. From a review of existing data a hypothesis has been formulated which the tests reported herein show to be reasonably accurate in predicting the fatigue life of a member or joint subjected to a variable loading cycle.

From the limited number of tests conducted, it may be concluded that the variations in maximum cyclic stress obtained in railway bridges may be expected to provide a life markedly greater than one would expect to obtain on the basis of the maximum applied stresses. However, it appears also that all of the loading cycles, even those at the lower stresses, have an effect on the life of a member and must be considered in any evaluation of the member's fatigue resistance.

B. INTRODUCTION

1. Preliminary Remarks

In this age of fast-moving vehicles and high-speed machinery, engineers are often confronted with problems which were not important a number of years ago. Not only must present-day structural elements often sustain higher stresses than formerly, but in many cases they must also sustain a larger number of repetitions of these stresses. Of the many problems in our modern technology few are as perplexing as those of guarding against failures of metal by fatigue.

Fatigue failures are difficult to anticipate because so little is known about the basic nature of fatigue. There are questions as to how the cracks originate and how fast they are likely to grow under repeated loadings, when does fatigue damage begin and how does it accumulate? Qualitatively, it is known that points of high stress concentration are danger points for fatigue failures. Therefore, actual tests must be conducted on specific parts, which are loaded precisely as they are in service and under similar environmental conditions, before a reasonably accurate estimate of the faitgue life can be ascertained.

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[2] Engineer, Boeing Airplane Co., Seattle, Wash. Formerly, research assistant of civil engineering, University of Illinois.
[3] Structural engineer, Rust Engineering Co., Birmingham, Ala. Formerly, research assistant of civil engineering, University of Illinois.

Since the formation of a fatigue crack is a very localized phenomenon, its place and time of inception depend not only on the geometry and general stress condition in the part, but also on the textural stresses in the metal at critically stressed regions. The size, shape, and orientation of the individual grains as well as their crystalline structure and boundaries all influence the formation and growth of the crack from a microscopic or submicroscopic point of weakness until it can be seen with the naked eye. Any influence that affects the mechanical behavior of the metal can certainly be expected to have some effect on its fatigue properties. However, attempts to predict the fatigue life of a metal from a knowledge of its various measurable properties have not met with complete success for even the simplest type of specimen and a constant stress cycle.

2. Fatigue Damage Studies

Studies were started more than 20 years ago to try to correlate the fatigue lives of standard-type specimens which have been subjected to mixed cycles of stress with conventional S–N relationships for the same type of specimen. Most of this research has been done on round polished specimens stressed in reversed bending; however, some tests have been made using direct axial loads.

The earlier investigations of this type dealt with the effects of cycles of overstress* on the endurance limit of a given material. French[1]** defined a so-called "damage line" by this type of testing. This damage line is determined in the following manner: An S–N curve is first obtained, using all virgin specimens. Then several more identical specimens are run at a low overstress for various fractions of their normal lifetime as determined by the S–N relationship. Each of these "prestressed" specimens is then cycled at the endurance or fatigue limit[2]***. If a specimen fails while being run at the fatigue limit, it is assumed to have been damaged by the prestressing operation at the overstress. One that does not fail after a sufficiently large number of cycles is assumed to have accumulated no damage. Other series of specimens are then tested in a similar manner at other overstresses until it is possible to interpolate between the number of cycles applied to the specimens of each overstress series and determine a point where no damage is inflicted on the fatigue limit. The locus of such points at the various overstresses then determines the damage line.

Similar tests have also been conducted by Moore[3], Kommers[4, 5] and others. Kommers determined new fatigue limits for the prestressed specimens. He then expressed the damage as the percent change in the initial fatigue limit caused by the prestressing, where either understresses or overstresses were used as the prestress. His results indicate that there is a rapid increase in damage with an increase in the number of cycles at the higher overstresses. That is, damage increases at an increasing rate with the number of overstress cycles applied. He concluded that a material which has been subjected to an overstress and then to an understress finally fails at a stress below the initial fatigue limit, because overstressing causes a decrease in the initial fatigue limit. Other observations showed that for some materials there appeared to be an actual increase of the fatigue limit due to some cycling at low overstresses. Apparently, these materials

* An overstress or understress is defined as a cyclic stress greater or less than the endurance limit, respectively.

** Numbers in parentheses refer to references in the Bibliography.

*** The American Society for Testing Material, Manual on Fatigue Testing, considers the term "fatigue limit" preferable to endurance limit.

were not damaged significantly until a very large percentage of the normal fatigue life at these overstresses had been expended.

Lea[6] conducted overstress and understress tests on an annealed 0.32 percent carbon steel having a tensile strength of 72,000 psi and a rotating beam fatigue limit of 32,000 psi. The estimated fatigue life at 40,000 psi was 12,500 cycles. By cycling a specimen just under the fatigue limit and by repeatedly increasing the stress in small increments up to 40,000 psi, it was possible to apply 40,000,000 cycles at the latter stress level before failure occurred. The normal life at 40,000 psi had been increased 3,350 times. Swanger and France[7] also report some interesting results similar to these. This type of testing is reported in many places in the literature and is generally known as coaxing.

Gough[8] and many other investigators believe that understressing tends to work-out the peak textural stresses in the virgin material into a more homogeneous distribution and, in effect, increases the fatigue limit. Overstressing, on the other hand, is believed to aggravate the textural stress condition by more severe plastic deformation, particularly in the partially unrestrained material at the surfaces. It is here that fatigue cracks generally form.

Much of the fatigue damage work reported in the literature has been along the lines discussed above. It is not directly applicable to design problems, but it has aided greatly in providing a better general understanding of fatigue damage from a phenomenological viewpoint.

3. Cumulative Damage in Fatigue

Most so-called cumulative fatigue damage studies have been concerned with the effects of prestressing at one overstress on the subsequent endurance at another overstress or "test stress". These studies have led to methods for estimating the fatigue lives for variable-stress-cycle loading and can be applied to certain design problems. Important general conclusions can also be drawn from these more recent investigations. For the purpose of discussing these conclusions, the following terminology will be used:

$S =$ Maximum stress of a stress cycle.
$N =$ Number of cycles to *failure,* applied to a specimen at a stress, S.
$n =$ The number of cycles endured at any stage of a fatigue test at a stress, S. n always less than N.
$R =$ Cycle ratio, the ratio of the number of stress cycles applied at a given stress level to the expected fatigue life as estimated from the S–N curve for that stress level, $R = n/N$.
$D =$ Fatigue damage done to a specimen by previous fatigue stressing, measured as the percent shortening or lengthening of the fatigue life at the final or test stress level.

Palmgren[9, 10] is reported to have suggested a method for analyzing data for fatigue tests at several stress levels. The method was then considered by Miner,[11] Luthander and Wallgren[12], and others for design purposes. Miner conducted tests on 24S–T aluminum alloy plain sheets and riveted joints, and the method generally carries his name in this country.

In analyzing data by this method, it is assumed that there is a linear relationship between the prestress cycle ratio and damage at any given overstress level, and furthermore, that during the course of any fatigue test, the damage is equal to the summation of all of the prestress cycle ratios. Thus, the damage, D, and the cycle ratio, R, would

be equal to n/N for each block of cyclic stress applied, and would sum to unity at failure.

Müller-Stock, Gerold, and Schulz[13], Kommers[14], Richart and Newmark[15], and other investigators have shown that such a simple relationship between damage and cycle ratio does not actually apply, but that damage more likely varies with some power of the cycle ratio.

In some of these investigations only two different stress levels were used. Thus, the effect of a certain block of prestress cycles could provide either a healing or damaging effect to the remaining endurance at a different test stress. For example, if after n_1 cycles at a stress S_1, a specimen is cycled to failure at a different stress level, S_2, the cumulative cycle ratio is n_1/N_1 plus n_2/N_2 and should be equal to 1.0 according to Miner's theory. However, in most cases it was found to be greater or less than unity.

It has been demonstrated that the order in which the stresses are applied makes a difference in the total number of cycles to failure. That is, an initial maximum cyclic stress, S_1, greater than the final stress, S_2, ordinarily gives a cumulative cycle ratio less than 1.0, while an initial stress less than the final stress may give a value of cumulative cycle ratio greater than 1.0.

Richart and Newmark[15] showed that as the number of alternate blocks increased without bound the value of the cumulative cycle ratio appeared to converge to some definite value regardless of which stress block had been applied first. But even then, the cumulative cycle ratio was usually different from unity. It appears that a cumulative cycle ratio most nearly equal to unity will occur when the prestress and test stress are nearly the same. This is to be expected, because the constant-cycle fatigue lives at the two stress levels would be very nearly equal.

A point that stands out in nearly all of these tests is that a specimen which is being cycled in fatigue is in a nearly constant state of change, particularly if the maximum stress of the cycle is an overstress. If a given set of specimens were all cycled at a constant maximum stress for an equal number of cycles, and then an S–N diagram determined using these prestressed specimens, and including the cycles of prestress in the new plot, the new diagram would cross the S–N diagram for the original specimens at the value of the prestress. This would occur because continued cycling of a prestressed specimen at the prestress value would cause failure as predicted by the original S–N diagram. Also, it has been shown by test that prestressed specimens will give a new S–N diagram. However, the fatigue lives are usually more scattered than for tests at a single stress level.

Fig. 1 shows some of the results of tests made by Kommers[14] on rotating-beam specimens of SAE 1020 steel. The upper diagram in this figure shows the new S–N relationships that were determined *after* prestressing the specimens at 36,000 psi for various prestress cycle ratios, R. The lower diagram shows the same test data except that the cycles of prestress are *included* with the test stress cycles to failure.

It may be noted that the "rotation" of the diagrams with respect to the basic S–N curve or a vertical line through the point of rotation is proportional approximately to the cycle ratio of the prestress. Thus, for zero cycles of prestress, $R = 0$, a test point would lie on the S–N curve, and for $R = 1.0$, the specimen would fail before any test stress cycles could be applied. In the latter case, the point representing zero cycles of test stress would be plotted on the vertical line through the point of rotation.

From a study of Kommers'[14] data and tests by Bennet[16] and others, it appears that S–N diagrams for prestressed specimens will "rotate" in a clockwise fashion about

the point on the original S–N diagram corresponding to the value of the prestress. This illustrates some of the principal findings of the earlier fatigue damage studies—that a high overstress has a damaging effect on the subsequent remaining fatigue life at a lower stress, and that a low stress tends to show a healing effect on the endurance at a higher subsequent stress.

A possible effect of prestressing specimens at one or more values of prestress is further indicated in Fig. 2. In this illustration it is assumed that an overstress, S_1, is applied to all of the specimens for n_1 cycles. The specimens will be sufficiently changed by this prestressing operation that they will yield an S–N curve different from that of the original specimens. If this new S–N curve is determined and if the cycles of prestress are included in its representation, a curve such as 2–2 will result. Two things may be noted concerning curve 2–2: first, it crosses the original S–N diagram at the value of the prestress, and second, it is rotated in a clockwise direction with respect to the original diagram. If, after cycling at S_1 for n_1 cycles, the specimens were subjected to an additional n_2 cycles at S_2 and another S–N relationship were established including the cycles n_1 plus n_2, a curve such as 3–3 would possibly result.

This implies that if the applied cyclic stresses are always within the finite life range of the basic S–N relationship, the fatigue life can be bracketed on the original diagram between the numbers of cycles required to cause failure at the upper and lower maximum cyclic stresses. Presumably, the location of the point representing the number of cycles to failure would fall within this bracket and would be a function of the general configuration of the blocks of the applied cyclic stresses. Of course, an approximation for an equivalent random variation in stress cycles could be attained only if the pattern of blocks of stresses were repeated a sufficiently large number of times such that the order of the application of the stresses within the pattern or *spectrum* would make no discernable difference in the total number of cycles to failure.

Damage curves can be utilized to compare this observation with test data. If the damage is equal to the cycle ratio as Miner and others have surmised, then curves of constant fatigue damage are the same as curves of constant prestress cycle ratio. It is possible, then, to construct curves of constant damage by using Miner's theory and an S–N diagram. For this type of plot, the basic S–N diagram is the curve for a damage of 1.0. The data from Kommers'[14] tests, as shown in Fig. 1, have been replotted in Fig. 3. The solid curves in the upper diagram show the number of cycles to failure *after* various cycle ratios, R, of the 36,000 psi prestress have been applied. The dashed-line curves are loci of constant fatigue damage from Miner's theory due to prestressing at 36,000 psi. The basic S–N diagram is obtained by test-stress cycles only; therefore, the prestress cycle ratio for this curve is zero. The number of cycles between the dashed-line damage curve, $D = 0.2$, and the basic S–N diagram, $R = 0$, corresponds to 0.8 of the fatigue life at the test stress, because the total or cumulative cycle ratio must be 1.0.

The lower part of Fig. 3 shows the *total* number of cycles to failure including the cycles of prestress at 36,000 psi. The dashed-line curves are those predicted by Miner's theory, and the two solid curves, $R = 0$ and $R = 0.8$, are those determined by Kommers' tests. These curves clearly illustrate one serious defect in Miner's theory, the assumption that no damage is entailed when cycling below the fatigue limit. The diagram also shows that the failure may occur at 1,000,000 cycles at a stress approximately 3,000 psi below the fatigue limit after a cycle ratio of 0.8 had been applied at the prestress. Certainly these stresses below the fatigue limit and their effect on the fatigue life cannot be discounted.

4. Object and Scope of Investigation

The objectives of the research program described herein were:

1. To complete the design and construction of a 50,000-lb variable-cycle fatigue testing machine and programming apparatus to test structural joint specimens.
2. To review past investigations in cumulative fatigue damage and to correlate the findings with the present study.
3. To determine the fatigue lives of double-strap butt joint specimens and plain plate specimens when tested in pulsating tension under a loading pattern which approximates the statistical distribution of service loads on present-day medium-span, main-line railway bridges.

Evaluations of variable-cycle fatigue tests in previous investigations have been based on conventional S–N relationships for the specimens. In order to make a correlation, the stress cycle used for both constant and variable-cycle tests must have a common basis of comparison. The mean stress, the minimum or maximum stresses, or the type of stress cycle (zero to tension, etc.) must be held constant. But, in the actual structure, there may be no well defined minimum or maximum stresses to which a member is subjected. It is logical to believe, however, that variations in stress at the smallest stress levels are of less significance than those due to heavy live loads and impact. Thus, the maximum stresses and the cyclic variation in these stresses are of principal interest in this study.

If representative samples of these maximum cyclic stresses for a structural element are ascertained and sorted according to decreasing magnitudes, a load-frequency spectrum can be constructed. The research staff of the Association of American Railroads has conducted a number of field studies[17, 18] to determine the static and dynamic effects in plate-girder bridges resulting from the passage of trains. It is evident from a study of the reports on this work that the maximum stress in the girders was not obtained with the passage of each train, but rather by only a small percentage of the trains. The nature of the frequency-distribution spectrum for the maximum stresses obtained in the AAR tests is presented in Fig. 4.

If such a frequency spectrum is used as the envelope of the maximum cyclic stresses over a given number of cycles, and if a fixed minimum stress is established, then the data from fatigue tests conducted according to this stress pattern could be compared with constant-cycle fatigue tests having the same fixed minimum stress. The fatigue lives obtained by cycling under this spectrum-type pattern should be more nearly congruent with actual fatigue lives under service conditions than data from constant-cycle tests.

For the present study the maximum cyclic stresses are varied as a sine wave from some major maximum stress value, S_A, to a minor maximum, S_a, one-half as great. It is believed that this pattern approximates reasonably well the frequency distribution data obtained in the field. Under this sine-wave type of pattern, part of the stress cycles will be below the fatigue limit. From a study of the previously mentioned investigations it was somewhat uncertain what effect these lower stresses would have on the fatigue life.

According to Miner's theory, the value of the cumulative cycle ratio for stresses below the fatigue limit is always zero because the number of cycles to failure at these low stresses is infinite. But, it is known that overstressing can lower the fatigue limit and also that understressing can coax the fatigue limit upward for some materials.

With these questions in mind, it was necessary to study other variable-cycle fatigue data wherein various loading spectrums were used and where some of the stress cycles were below the fatigue limit for the original material. It was hoped that such a study would reveal a method for approximating empirically the fatigue lives of structural joints when tested under any given loading spectrum.

5. Acknowledgment

The study described herein is part of an investigation carried on as a result of a cooperative agreement between the Engineering Experiment Station of the University of Illinois, the Illinois Division of Highways, the Department of Commerce—Bureau of Public Roads, and the Research Council on Riveted and Bolted Structural Joints. It is part of the structural research program of the Department of Civil Engineering of which Professor N. M. Newmark is Head. Much of the work was carried out and the damage hypothesis developed by J. R. Fuller, formerly a research assistant in civil engineering, as a part of his work on a doctoral thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Engineering.

All units for the variable-cycle fatigue testing machine used for this investigation were constructed in the Structural Laboratory at the University of Illinois. All machine shop work was carried on under the supervision of D. F. Lange, supervisor in the Civil Engineering Shop in the Laboratory. Initial portions of the design for the variable cycle machine were completed by W. J. Hall, associate professor of civil engineering[23]. The other parts of the machine for activating both the mean-load and range-control mechanisms, and the mechanical portions of the programming unit were designed by J. R. Fuller. V. J. McDonald, associate professor of civil engineering, designed the electrical portion of the control and programming systems.

The tests described herein were planned with the advice of the Project VIII Committee of the Research Council on Riveted and Bolted Structural Joints. This committee is concerned with cumulative damage in the fatigue of structural joints. The members of the committee are as follows:

W. H. Munse (chairman), Raymond Archibald, J. W. Carter, K. H. Lenzen, Frank Baron, N. M. Newmark, E. J. Ruble, V. M. Romine, E. W. Larson.

C. DISCUSSION OF OTHER TESTS

1. Spectrum-Type Fatigue Tests

If a specimen is cycled under some variable load pattern between two limiting overstresses, the greater of which is S_A and the smaller S_a, then failure may be expected to occur at some number of cycles greater than that which would cause failure by cycling at S_A alone and less than that which would cause failure by cycling at S_a alone. Thus, by cycling under some variable load pattern whose upper and lower bounds are overstresses, it would seem likely that the fatigue life would be a function of the variable load pattern and the stress levels, and that it could be related to the basic S–N diagram.

Dolan, Richart, and Work[19] conducted a rather extensive series of tests on notched and unnotched rotating-beam specimens of several materials using three different variable load patterns, which they refer to as load cycles B, A, and G, respectively. Two of these patterns, B and A, were of the rectangular two-stress-level block type, and the third, pattern G, was a sine wave. All three had a duration of 10,000 cycles. For pur-

poses of discussion, only the results of the tests on the steel specimens from the above paper will be considered.

In this work of Dolan et al, the major (larger) maximum stress, S_A, was always an overstress, and the minor (lesser) maximum cyclic stress, S_a, was either an overstress or an understress. Also, the major maximum stress, S_A, was varied from specimen to specimen, while the minor maximum, S_a, was held constant. The results of load cycle B tests on SAE 1045, where both S_A and S_a were overstresses, are shown in Fig. 5.

The variable-cycle test results shown in this diagram are plotted at the major maximum stress value; all test points having the same minor maximum stress are represented by the dashed curves. Thus, curve 2 represents test results wherein S_a was 60,000 psi and S_A was selected between 60,000 psi and 75,000 psi. Naturally, these dashed curves must intersect the S–N diagram at the value of the minor maximum stress, S_a, because at this point there was no variation in the maximum stress.

It is of particular interest to note that these curves are nearly parallel even though a rather limited amount of data is presented. This suggests that the slopes of the dashed curves may be a function of the loading spectrum used for these specimens and that the ratio of the slope of the S–N curve, k_{SN}, to the slope of the variable cycle curves, k_v, may be a constant and may depend only on some function of the variable-cycle pattern.

Other similar tests were conducted on SAE 4340 specimens for which S_a was considerably below the fatigue limit. One group was tested at a value of S_a equal to 78,000 psi and another at 60,000 psi. As in the previous tests, the type B load cycle was used. Fig. 6 shows the results of these tests. In these diagrams, the authors approximated the experimental data by the solid curves as indicated. However, straight lines would appear to fit the variable-cycle test results equally well.

For the tests of SAE 1045, where both S_A and S_a were overstresses, it was evident that the variable-cycle curves must intersect the S–N diagram at S_a in each case. Also, the test results for the SAE 4340 specimens show that the variable-cycle straight lines, when extended, intersect the extended "sloped-leg" of the S–N diagram at S_a. This occurs even though a new fatigue limit is obtained above the fatigue limit of the initial S–N curve.

The type B load cycle used in the tests of SAE 4340 consisted of 1,000 cycles of S_A and 9,000 cycles of S_a, where S_a was below the fatigue limit. Thus, the fatigue lives, as computed by Miner's theory, would be 10 times the number of cycles as indicated for each point on the initial S–N curve. Of course, Miner's curve would terminate at the fatigue limit of the S–N diagram. These curves and those ascertained by the authors may be compared with the test results on the diagrams in Fig. 6.

If the slopes of these two variable cycle curves are a function only of the distribution pattern they should be identical, because the testing apparatus, the specimens, and the load pattern were the same for both series; only the value of S_a was different. An inspection of these curves shows that this may well be the case.

Tests similar to those previously discussed were also conducted using load cycle A, which consisted of 5,000 cycles of S_A and 5,000 cycles of S_a. The results of these tests are shown in Fig. 7. From these results it is evident that the variable-cycle curve lies quite close to the S–N diagram even though the test results are somewhat more erratic and even fall to the left of the S–N curve at times. As would be expected, the slope of the variable-cycle curve more nearly approaches the slope of the S–N diagram,

because more cycles of S_A were included in the load pattern. Thus, the ratio of k_{SN} to k_r should be nearer unity.

With the data presented in the tests using the two load patterns B and A as a basis, it is possible to interpolate for the expected relationships for other patterns having different ratios of N_A to $(N_A + N_a)$; where N_A and N_a represent the number of cycles in a load pattern at S_A and S_a, respectively.

If the load pattern was constant at S_A, where S_A is any overstress, then failure would occur on the S–N diagram and the ratio of k_{SN} to k_r would be 1.0. But if only a very small percentage of the load pattern cycles were at S_A and the remainder at S_a, then the slope of a variable-cycle curve so determined would be extremely high and, in theory, would approach a vertical line through the point (N_a, S_a) on the S–N diagram. In the latter case the ratio of k_{SN} to k_r would approach zero as k_r becomes infinite.

If the ratio of k_{SN}/k_r is set equal to β, where

$$0 < \beta \leqq 1.0,$$

then the two limiting points of β, (0 and 1.0), together with the two interior points determined from Dolan's tests provide four points on a curve,

$$\beta = f\left(\frac{N_A}{N_A + N_a}\right) \quad \ldots\ldots (1)$$

This relationship has been plotted as a solid line in Fig. 8 and approximated by the dashed-line curve. The equation for this dashed-line curve is

$$\beta = \frac{1}{3} \log_{10}\left(\frac{1000\, N_A}{N_A + N_a}\right) \quad \ldots\ldots (2)$$

In the cumulative frequency-distribution spectrum for girder bridges shown in Fig. 4 the percentage of total loadings exceeding a given stress are presented in teams of the maximum stress. If we consider this same decreasing order for a 1,000-cycle load pattern between S_A and S_a and plot it on a 3-cycle log plot, the ratio of the area under this log-distribution pattern (from $\log_{10} 1.0 = 0$ to $\log_{10} 1000 = 3.0$ and from S_A to S_a) to the area of the field on which it is plotted is equal to the distribution coefficient, β, as previously defined. The stress cycles greater than S_a produce a block of area equal to $\log\left(\frac{1000\, N_A}{N_A + N_a}\right)$. Thus, β may be taken equal to the above mentioned block divided by the area of the entire field, which was 1.0 times $\log_{10} 1000$ or 3.0.

On the basis of a 1,000-cycle load pattern, load cycle B of Dolan's tests[19] would have 100 cycles at S_A and 900 cycles at S_a. The minor maximum stress, S_a, is the lower limit of the plot, and cycles at this stress will not contribute to the area being computed but cycles of greater stress will. Therefore,

$$\beta_B = \frac{\log 100}{\log 1000} = \frac{2}{3} = 0.67$$

For load cycle A there would be 500 cycles at S_A and 500 cycles at S_a, and the distribution coefficient, β_A, could be computed as follows:

$$\beta_A = \frac{\log 500}{\log 1000} = \frac{2.7}{3} = 0.9$$

Of course, if all cycles were at S_a, β would be zero; if all were at S_A, β would equal 1.0.

Thus far, patterns having only two stress levels, one at S_A and the other at S_a, have been considered. However, it is necessary to consider loading spectrums of multi-stress levels for the method to be of any appreciable value.

Dolan's load cycle G varied as a sine wave between S_A and S_a. The results of these tests are shown in Fig. 9. In this diagram the dashed-line drawn through the test results has a value of β equal to 0.90. The value of β based on the above noted area procedure has been computed for a sine wave frequency-distribution spectrum. Fig. 10 (a) shows the frequency-distribution spectrum, and Fig. 10 (b) shows the resulting 1,000-cycle log-distribution pattern. It may be noted that the value of β computed in Fig. 10 (b) is 0.90, which is identical with the above test value.

Another point which is of interest in this discussion is that at any given stress level the value of β may also be represented as the ratio of the actual horizontal distance between the variable-cycle diagram and a vertical line through the S–N diagram (or S–N diagram extended) at S_a, to the distance from the basic S–N diagram to the same vertical line at the same stress level. Thus, in the previous diagrams in Figs. 6, 7, and 9, which show the results of tests by Dolan et al, the ratio of BC to AC (or in Fig. 6 for $S_a = 60{,}000$ psi and load cycle B, the ratio of B′C′ to AC′) is the same as the ratio of k_{SN} to k_v and equal to β.

If the distribution coefficient, β, is known, the number of cycles to failure under a spectrum-type loading pattern may be expressed as N_v where

$$\log N_v = \log N_a - \beta (\log N_a - \log N_A),$$

and

$$N_v = N_a \left(\frac{N_A}{N_a}\right)^{\beta} = N_A{}^{\beta} / N_a{}^{(\beta-1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

It should be mentioned again in connection with the previously discussed variable-cycle tests and the foregoing analysis, that all of the variable-cycle results were plotted at S_A, the major maximum cyclic stress. This would seem to be the logical way to identify the test results. However, if a variable-cycle test value plotted at S_A were projected vertically downward onto the S–N curve, it would indicate a constant stress cycle which would have the same fatigue life and which could be considered as an equivalent constant stress cycle.

Freudenthal[20] has conducted variable-cycle rotating-beam tests on 24S–T4 and 75S–T6 aluminum alloys. For purposes of comparison, however, only the 75S–T6 tests will be discussed here.

Twenty specimens were tested at each of six different stress levels for a careful determination of the S–N diagram. Also, 20 specimens were tested at identical stress levels for each of 9 different distribution patterns.

The nine distribution patterns (A, B, C) (A′, B′, C′), and (A″, B″, C″) are shown in Figs. 11 and 12. The 3-cycle log-distributions are adjacent to each frequency distribution pattern. In the log-distribution patterns, the ratio of the shaded area to total block area yields the value of β in each case.

The results of Freudenthal's tests on 75S–T6 are presented in Fig. 13. All points plotted on this diagram were obtained as the anti-log of the mean log N for 20 separate tests. Thus, the 300 tests represented on this figure provide some of the most extensive information yet obtained in a cumulative damage study.

The test results for the nine variable cycle load patterns have been plotted at S_A, and the results based on the computed values of β have been plotted above the actual test results and connected to them by short solid lines for purposes of comparison. The

results are also presented in a tabular form in Table 1. It may be noted that the average net error was only 1.52 percent. Those distributions which showed the greatest error are A, C, B′, and C″, but no reason for these larger deviations can be determined. If these four patterns are considered alone, the average net error is only 2.91 percent.

Thus, it would appear that the previously described method of estimating the fatigue lives of specimens or parts which are subjected to variable-load patterns need not be complicated to conform exactly with any given set of results. The method appears to yield values that are within the accuracy of the test results themselves.

2. Statistical Nature of Fatigue Test Results

Obviously, the experimental scatter of fatigue-test results can be minimized by making the specimens as nearly identical as possible, both metallurgically and geometrically, and by carefully controlling the testing apparatus and procedure. Nevertheless, the aggregate nature of the metal as well as the chance distribution of minute inclusions and other points of weakness may cause significant experimental variations.

An ordinary S–N curve usually shows the relationship between the maximum cyclic stress for a defined stress cycle and the number of cycles of this stress which a given type of test specimen will endure until failure occurs. The curve implies that there exists a unique relationship between the maximum cyclic stress and the cycles to failure and that failure has been precisely defined.

If failure in a specimen is defined as the number of cycles endured until the appearance of a crack, then the number of cycles to failure depends on how closely and how often the specimen is inspected during the course of the test. Visible cracks have been detected in fatigue specimens at as little as 10 to 50 percent of the total cycles to complete rupture[21]. Therefore, some criterion for failure must be established. Also, since dispersion in the data is inherent, some method of choosing a value within this range of dispersion must be defined before an S–N diagram can be uniquely established for a given set of data.

A statistical interpretation of the results of a number of measurements, such as the number of cycles to failure for identical specimens, requires some assumption concerning the distribution of fatigue lives for an infinite number of identical tests. If the nature of the distribution is known, it is then possible to apply approximate statistical methods to the results of a relatively small number of tests to ascertain a representative mean result and to arrive at an estimate of the dispersion or deviation from this mean value.

Several investigators have conducted a large number of identical tests to determine the nature of the distribution of fatigue lives[13, 22]. The results of 235 tests by Müller–Stock, Gerold, and Schulz[13] on steel specimens (German St 37) subjected to reversed bending at approximately 45,500 psi and results obtained by Sinclair and Dolan[22] for 57 rotating-beam tests on 75S–T aluminum alloy are shown in Fig. 14. Data from Müller–Stock's frequency density diagram have been replotted to a log scale. The data given by Sinclair and Dolan are presented herein as they were reported.

An examination of these results indicates that the distributions are both skewed to the left with regard to the number of cycles to failure, N, but appear to be approximately normal with regard to log N. Other investigators have demonstrated results very similar to these.

If the fatigue life frequency density curve can be considered normal with respect to the logarithm of the number of cycles to failure, then the best estimate for the mean fatigue life would be the anti-log of the mean log N, where the mean log N for m tests is

$$\overline{\log N} = \frac{1}{m} \sum_{i=1}^{m} \log N_i \quad \ldots\ldots (4)$$

The anti-log of $\overline{\log N}$ or $\overline{N}$ is then assumed to be the number of cycles for a 50 percent probability of failure or 50 percent probability of survival, and as such it will represent the best average point on the ordinary S–N diagram for the particular stress level used.

Since the distribution of fatigue lives in a given population appears to be approximately normal with respect to log N, it is possible to approximate a range of log N wherein a certain percentage of a sufficiently large number of specimens will probably fail, or to establish the number of cycles for a given probability of failure, p_f, or of survival, p_s, where $p_s = 1 - p_f$

The standard deviation is often used as an indication of the dispersion of this type of experimental data. It represents half the distance between the points of inflection on the Gaussian (normal) distribution curve and is given by σ, where

$$\sigma = \left[\frac{1}{m} \sum_{i=1}^{m} (\log N_i - \overline{\log N})^2 \right]^{1/2} \quad \ldots\ldots (5)$$

In a Gaussian distribution 68.3 percent of the observations will fall within a distance of σ of the mean, or for these purposes within σ of $\overline{\log N}$. W. Weibull* made these remarks in his discussion of Freudenthal's contribution to the Symposium on Statistical Aspects of Fatigue[23]:

"The number of specimens at each stress level depends on the information wanted. The mean or median of the fatigue lives may be sufficiently accurately estimated from 6 to 10 specimens at each stress. The scatter measured for instance by the standard deviation may demand 20, but the distribution will not be too accurately determined with 100 specimens at each stress."

If the distribution of fatigue test results for a given population is log-normal, then a representation of the frequency of failure or survival versus log N will appear as a straight line when plotted on a log-normal probability paper. Of course, it is necessary to have a sufficient number of tests of the same population to determine accurately such a relationship, but a modification of this type of presentation can be used for comparison purpuses for several small populations of tests on similar specimens.

If a series of m identical fatigue tests are arranged in order of increasing fatigue life and are numbered consecutively from 1 to m, $(1 \leq n \leq m)$, the relative frequency of failure may be taken as $n/(m+1)$. Naturally, the reliability of such a value decreases with a smaller number of tests, such that for three or four test results in a given population it may be entirely misleading if it is interpreted alone. Therefore, it must be evaluated with similar data for other stress level populations for the same type of specimen and stress cycle. There is usually less dispersion in the fatigue lives of specimens tested at high stresses than at low stresses. Hence, a log-normal distribution plot for a high stress level should have a greater slope than for a lower stress level. It appears that this method provides a valuable tool for the analysis of fatigue data where only a small number of test results can be obtained.

* Scientific director of the Bofors Company, Bofors, Sweden.

D. TEST EQUIPMENT

1. Variable-Cycle Fatigue Machine

In order to study the fatigue lives of structural members subjected to various patterns of cyclic stresses, a control unit has been developed so that the stress cycle can be changed automatically according to prearranged patterns.

The machine on which this control is used is a W. M. Wilson-type machine, has a maximum load capacity of 50,000 lb and is a lever-type mechanism. The lever ratio of the walking beam is 10 to 1, and it operates at approximately 300 cycles per minute. It may be noted from the line drawing of the machine in Fig. 15 and the schematic diagrams showing the linkage or range control mechanism in Fig. 16, that the machine has a fixed eccentric which, in turn, drives an adjustable linkage arrangement[24]. This linkage allows the amplitude of the stress cycle to be changed while the machine is in operation. One end of the linkage bar, as shown in Fig. 16, is pinned (at M) to an adjustable quadrant which can be moved about a fixed center by gears and a reversible motor.

The movement of the lower end of the linkage bar causes a variation in the vertical component of movement of the bar, at point C, and hence a change in the vertical movement of the walking beam of the machine. When the pin at M is in its upper position, as shown in Fig. 16 (a), a maximum vertical movement of 1.57 in per cycle is obtained at point C. Figure 16 (b) shows the pin at M in the lowest position where this movement is reduced to 0.33 in per cycle. Thus, the desired amplitude can be obtained by the proper positioning of the quadrant between these limits.

The mean or average cyclic load is varied by means of the gear-nut (turnbuckle) arrangement shown in Fig. 15 and 17 (a). Mechanical power is applied to this gear-nut through a train of three spur gears in the gear-nut assembly; it is driven by a shaft which is mounted on the walking beam. The shaft runs parallel to the axis of the beam to a point just above the pullheads, where power is supplied by another motor through a gear reducer. The shaft is equipped with two universal joints to take up the angular displacements of the walking beam and the gear-nut. One of these joints is at the fulcrum of the beam, and the other is opposite the pin through which the lever force is applied at the eccentric end of the beam.

To eliminate the impact effect due to looseness in the gear-nut, two large compression springs were placed under the gear-nut box. These springs maintain an internal force between the gear-nut sleeve and screw and keep the threads in constant contact in one direction for all portions of the load cycle. With this arrangement, a smooth load-time record has been obtained. Fig. 17 (a) shows the gear-nut assembly with these springs in place. Fig. 17 (b) shows the quadrant or range control mechanism.

When a crack forms in an axially loaded fatigue test specimen, its over-all length changes. This change in length is utilized in the machine to detect failure. When the specimen begins to elongate, a micro-switch which is mounted on the fulcrum column is activated by a bracket rigidly attached to the upper pullhead, and the machine power is cut off.

Limit switches have also been installed on the gear-nut and quadrant assemblies and are shown in Figs. 15 and 17. These switches restrict the range of movement of the gear-nut screw into the sleeve and the angular movement of the quadrant such that if these ranges exceed that required by the program pattern the machine is stopped.

2. Electrical Control and Measurement System

The electrical control and measurement equipment operates between the output signal of the load-sensing device (weighbar) on the fatigue machine and the switches which activate the load-adjusting motors on the quadrant and gear-nut. It measures the actual load on the specimen, regulates the maximum and minimum cyclic loads to a predetermined program, and provides a complete permanent record of the test.

All components of the control system are shown in the block diagram in Fig. 18. Insofar as it was possible, commercial units available in the laboratory were used in this system. These were then modified as necessity dictated.

When the load on the machine is manually checked, the electrical signal from the weighbar, Block A in Fig. 18, can be measured on a portable SR–4 strain indicator, Block B, or on the dynamic load measuring and recording equipment, Block C. This signal can also be compared with readings taken from a calibrated bridge circuit, Block D, which is electrically identical with the weighbar circuit and is arranged to give outputs proportional to loads on the specimen of 0, 10, 20, 30, 40, and 50 kips. The calibration circuit can be switched into the recording equipment circuits to establish a scale on the dynamic records or into the portable strain indicator to establish readings for static load determinations.

The dynamic load measuring device, Block C, is a Sanborn Model 127 direct-writing strain recorder. This unit has been modified to insure long-time stability by the substitution of a closely regulated power supply and resistors which have improved temperature stability. Also, another paper speed has been obtained by attaching an auxiliary gear unit to the drive. This provides an extremely slow speed of 1 inch per 12 minutes (3600 machine cycles). Thus, the recorder provides a record which is essentially an envelope (maximum and minimum) of the load-time relationship for the specimen. The two standard paper speeds of 1/10 in and 1 in per sec, respectively, may be utilized to inspect the individual cycles of loading. A sample of the record for the slowest paper speed is shown in Fig. 19.

The electrical output from the Sanborn recorder is used to operate the load-control equipment. This output is fed into two peak-reading voltmeter circuits, one of which establishes a nearly constant output proportional to the maximum cyclic load, while the other performs an identical function for the minimum cyclic load. The zero electrical output from the Sanborn equipment is located approximately midway in the smallest load cycle when the equipment is set up for a test because it is necessary to provide a measurable electrical signal for both the minimum and maximum cyclic loads which are of opposite polarity.

The time constants of the peak-reading voltmeter circuits have been set so that the decay or drop-off in their output between machine cycles is less than the system dead-zone. These maximum and minimum load measuring circuits are shown as Blocks E in Fig. 18. Their outputs are fed into separate recorders (Leeds and Northrup Micromax units) to provide another permanent record of the load-time envelopes. These recorders are shown as Blocks F.

The outputs of the two peak-load measuring circuits also feed into separate peak-load indicators and control point selectors, Blocks G. These units are Wheelco Capacitrol Controllers that have been modified by the removal of their temperature compensation units and by increasing their dead-zone to approximately one percent of their full scale. In these units, pointed type galvonometers are used to indicate the peak cyclic loads.

The pointer in each unit also carries a small metal flag which passes between a pair of coils and affects their tuning when the control point is reached.

This tuning change in each unit is reflected into a circuit which operates an output relay and provides the following action. Below the control point, a low switch is closed; above the control point a high switch closure is made; and at the control point neither switch is closed. The programming operation is achieved by mechanically varying the positions of the control point coils along the scale. The action of these output switches on both the minimum and maximum peak-reading units is then used to control the two load-correcting motors on the fatigue machine.

Thus, a total of four switch actions at the outputs of the two controllers, Blocks G, indicate the status of the load cycle as compared with the specified program. These switches operate into a motor selector bank, Block H, that "decides" the direction in which either or both of the load-correcting motors must be turned to adjust the load cycle to agree with the specified program. Power is then applied to the motors through time-delay correction circuits as indicated by the Blocks J.

It will be noted from the above discussion that this is an on-off rather than a proportional control system; thus, it is necessary to control the rates at which the load-correcting motors adjust the load on the specimen. These delays or interruptors have been adjusted to provide the maximum system response commensurate with the minimum dead-zone width.

Power is applied to a correcting motor at a signal from the motor selector bank and for a period long enough to allow the motor to adjust the maximum or minimum cyclic load to approximately one half of the width of the dead-zone. Then the power is cut off for another interval as dictated by the time-delay circuit. This allows the measuring circuits to attain new readings. The same process of "adjusting and reading" is repeated three or four more times in an attempt to reach the dead-zone. If an error is still present, the power is applied continually until the load value crosses the control zone. After this action the process is repeated but in the opposite direction. It has been found in the present series of tests that about three "on" periods generally are sufficient to restore the load to the desired value. Some of the constants for the test system are given in Table 2. A view showing most of the load control and recording equipment is shown in Fig. 20.

3. Programming System

The programming operation is accomplished by mechanically varying the positions of the control-point coils in the Wheelco units along their respective scales. In the mechanical motor-driven programming unit, the maximum and minimum load program patterns are introduced by means of cams. Through a system of variable gearing, the length of time for the completion of one cycle of a load-frequency pattern can be adjusted to approximately 5, 10, 15, 30, or 60 min. In this system one cam programs the maximum and another the minimum cyclic loads. Both cams are driven from the same shaft, one on each face of the programmer. For the case of a constant minimum cyclic load, as was used in the present series of tests, only one part of the programmer was required.

One face of this programming unit is shown on the left in Fig. 21. Both cams in this unit displace followers which travel in horizontal slides at the same level as the cam drive shaft. Each slide then displaces a lever which, in turn, displaces another follower in a horizontal slide near the bottom of the unit. The levers which act between these slides have adjustable fulcrums that allow adjustments of the amplitudes of both

the maximum and minimum program variations. Horizontal wires are fastened to the lower slides and wound over pulleys on the positioning shaft of the control-point coils in the Wheelco units. Thus, the control-point coils are displaced in proportion to the radii of their respective cams.

E. DESCRIPTION OF SPECIMENS AND RESULTS OF TESTS

1. Specimens and Material

Double-strap butt-type joint specimens of structural A–7 steel* and plain plate specimens with a 1-in hole have been tested in this investigation. Details of these specimens are shown in Fig. 22. The plain plate specimens and the critical or center plate of the joints were of $\frac{5}{16}$-in material.

The fastener holes were sub-drilled $\frac{11}{32}$ in and reamed to $\frac{3}{8}$ in, with the center and side plates securely clamped together so that they lined up precisely when the specimens were assembled. After the joint plates were clamped and drilled, the edges were carefully milled to the proper edge distance. These joint specimens had a tension: shear:bearing ratio of 1.0:0.77:1.44**, and a net-section area of approximately 1.52 sq in. They were designed so that they could be tested at maximum cyclic loads up to the capacity of the fatigue machines, or approximately 50,000 lb.

The 1-in hole in the plain plate specimen was drilled full size. The edges of the plates were then milled to provide the desired width of specimen and to place the hole on the center lines of the specimen. These specimens had a net section area of approximately 0.781 sq in and were subjected to a maximum stress of 32,000 psi, or approximately 25,000 lb.

The mechanical properties of the $\frac{5}{16}$-in plate material as determined by standard laboratory coupon tests were found to be nearly constant throughout each plate; therefore, only the average mechanical properties are given in Table 3. Two different plate materials were used for these specimens; they are designated as A and B. Plate A was used for the joint specimens only, while plate B was used for both joint and plain plate specimens.

2. Joint Fasteners

Close-fitting stud-type fasteners were used in the joint specimens instead of rivets because their initial tension could be carefully controlled. It was desirable to control the fastener tension and the fabrication carefully to obtain consistent results in the fatigue tests. The studs were made of $2\frac{1}{4}$-in lengths of $\frac{3}{8}$-in cold-rolled rod. Both ends of the studs were threaded for a length of $\frac{5}{8}$-in to receive a mild steel washer and a heavy $\frac{3}{8}$-in hex-nut.

If it is assumed that the average tensile stress in a structural rivet is approximately 30,000 psi, then a $\frac{3}{8}$-in rivet would have a tension of 3,300 lb. In order that the joints would simulate riveted connections this load was chosen for the initial tension in the studs.

Load-elongation data were obtained for the studs at a grip of $\frac{13}{16}$-in, the nominal grip for the joint specimens. The average load-elongation relationship was found to be

* Steel meeting the requirements of the specifications for ASTM Designation: A-7, "Steel for Bridges and Buildings".

** The tension: shear: bearing ratio is the ratio of the tension area of the plate material at the critical net section to the net section tension area, the fastener shear area, and the bearing area, respectively.

940 lb per 0.001 in. In addition, load-torque data obtained in a bolt calibrator indicated an average load-torque relationship of 13.7 lb per in-lb.

Since the load-torque relationship could be determined easily and quickly in the calibrator, all of the fasteners for each specimen were calibrated. The average torque for a fastener tension of 3,300 lb was then determined for the 9 studs of each specimen prior to its final assembly.

The torques required to loosen the fasteners in each of the constant-cycle fatigue specimens, after testing, were averaged for each horizontal row fastener. These torques indicated average residual tensions in the studs, which were 62, 78, and 75 percent of the initial 3,300 lb tension for the first, second, and third rows, respectively.*

3. Constant-Cycle Fatigue Tests

Originally, eight constant-cycle fatigue tests at two different stress levels were planned for the joint specimens and three constant-cycle fatigue tests at one stress level for the plain plate specimens. However, it was necessary to increase the number of tests in order to determine the entire S–N diagram with a reasonable degree of accuracy. Thus, 18 joints and 28 plain plate specimens were tested, using a constant-stress cycle of pulsating tension from a minimum of 1,000 psi average tension on the net section to a maximum tension. Failure in all of these specimens occurred at the critical net section. For the joints the critical net section was at the first row of fasteners in the center plate. The fatigue cracks began at the outside fastener holes and progressed transverse to the direction of loading. When a sizable fatigue crack formed, the specimen would elongate sufficiently at the maximum cyclic load to activate a micro-switch which would stop the test.

The constant-cycle fatigue test data are given in Tables 4 and 5. To determine a relationship for the joint specimens which would approximate a 50 percent probability for failure, the anti-log of the mean log N or $\overline{\log N}$ was computed for stress levels of 32,000, 28,000 and 24,000 psi. It was found that these values of $\overline{\log N}$ could be very nearly plotted on a straight line when the logarithm of the average stress on the critical net section was taken as one axis. Therefore, the finite life portion of the S–N diagram, shown in Fig. 23, was drawn as a straight line on a log-log plot. Adopting the same type of equation as used by Wilson[25], this part of the diagram may be expressed by the relationship,

$$S = \frac{21{,}000\ (4{,}000{,}000)^k}{N^k} = \frac{163{,}500}{N^{0.135}}$$

where 4,000,000 represents the number of cycles to failure at a maximum cyclic stress of 21,000 psi, and k is the slope of the straight line approximation for the joint specimens. The value, N, represents the number of cycles to failure at a stress, S.

In a similar manner the S–N diagram for the plain plate specimens, shown in Fig. 24, was found to be expressible by the relationship,

$$S = \frac{207{,}700}{N^{0.149}}.$$

Tests of specimens identical to these plain plates specimens, except that all mill scale was removed by polishing, were tested previously by Stallmeyer[20]. The resulting S–N diagram for those tests is also shown in Fig. 24. It is immediately obvious that the behavior of the members used in these two studies varied somewhat. The mill scale on the plate surface apparently produces an increase in the fatigue strength.

* The "first" row of fasteners in a joint is defined as that row of fasteners which is located on the critical section of the joint.

The constant-cycle fatigue test data from the joint specimens were used also to ascertain plots indicating the relative frequency of failure versus the number of cycles to failure for three of the stress levels used to determine the S–N diagram. These plots were constructed by the method described previously, wherein the relative frequency of failure at a given stress was taken as $n/(m+1)$ for the n-th test of m ordered test results. The order is taken according to increasing cycles to failure. These logarithmic-normal probability diagrams are shown in Fig. 25.

These diagrams, which are rough approximations at best, indicate that the dispersions in the fatigue lives were nearly the same at all three stress levels. The values of $\overline{N}$ have been plotted at a frequency of failure of 50 percent in these diagrams. It may be noted that the dispersion of the results indicated for a stress of 24,000 psi appears to be less than that for 32,000 psi. This is contrary to other more extensive studies in that the dispersion at the lower stress levels is nearly always greater than for higher stress levels. The scatter band, which was merely drawn in to include all of the test data in Fig. 23, also indicates less dispersion at the lower stress levels than at the higher levels.

The S–N diagram for these constant-cycle tests indicates an extremely long finite life range. It has generally been found in other faitgue investigations on structural joints that the finite life range ends at about 2,000,000 cycles. For the present tests, however, the range extends to approximately 4,000,000 cycles, or nearly twice as long. This fact, naturally, increased the time required for failure at the low finite-life stresses and made the determination of the approximate location of the fatigue limit a very time-consuming operation.

The two 50,000-lb constant-cycle fatigue machines used to determine the basic S–N relationships are similar to the variable-cycle machine shown in Fig. 15 in both size and construction. All three of the testing machines operate at approximately 300 cycles per minute or 430,000 cycles in a 24-hr period. About 10 days of continuous machine operation were required to test a joint specimen to failure at a maximum cyclic stress of 21,000 psi. Therefore, because of the limited time available, only a few test results were obtained in the neighborhood of the fatigue limit.

4. Variable-Cycle Fatigue Tests

Sixteen joint specimens and five plain plate specimens were tested to failure in the variable-cycle study. Due to occasional mechanical or electrical failures in the testing equipment some of the specimens had a portion of irregular test pattern during the test, i.e., not all of the applied cycles followed the desired sine-wave variation. Consequently, extra specimens were run to compensate for these irrgular load patterns. However, an analysis of these load patterns showed that the maximum change in number of cycles to failure, if the specimens had run continuously with the desired pattern, would have been 3 percent and in the majority of cases it would be considerably less than 3 percent. This difference is negligible, and the specimens with irregular patterns are therefore included for the purposes of this investigation.

All variable-cycle specimens were tested in pulsating tension wherein the envelope of the maximum cyclic stresses was a sine wave. For this loading spectrum, the major maximum stress, S_A, was always twice the magnitude of the minor maximum stress, S_a, and the minimum cyclic stress was held constant at 1,000 psi as for the constant-cycle tests. All tests were begun at the minor maximum stress, S_a. The results of these tests are given in Tables 6 and 7.

In the variable-cycle tests, just as in the constant-cycle tests, the excessive elonga

tion of the specimen accompanying the formation of a fatigue crack was used to mark the end of the test and to stop the testing machine. Failure in all of the joint specimens occurred in the center plate at the first transverse row of fasteners except for one specimen which failed in the grip. As for the constant-cycle tests, the cracks began at the outside holes and progressed transverse to the direction of loading. The plain plate specimens also failed at the net section; the crack formed at the hole and then progressed transverse to the direction of loading.

The computed distribution coefficient, β_c, for a sine wave load frequency spectrum is 0.90 (see Fig. 10); therefore, the computed fatigue lives, N_{vc}, for the variable-cycle tests were determined by the previously derived expression,

$$N_{vc} = \frac{N_A{}^{\beta}}{N_a{}^{(\beta-1)}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

which is based on the basic S–N diagram. The predicted results for the variable-cycle fatigue tests are given in Table 8. The table also shows the ratios of test values to computed values of the number of cycles to failure, and the ratio of test to computed values of distribution coefficient β.

Fig. 26 shows the results of the variable-cycle joint tests as compared with the constant-cycle S–N diagram, the variable-cycle fatigue lives predicted by the method described in this investigation, and by Miner's theory. Fig. 27 shows similar data for the plain plate specimens.

In computing, by Miner's theory, the expected fatigue lives for the variable-cycle specimens, the number of cycles was determined for a cumulative cycle ratio of 1.0. For purposes of computation, a 1,000-cycle sine wave loading spectrum from S_A to S_a ($S_a = S_A/2$) was divided into 20 increments of 50 cycles each. The cycle ratio for the average stress in each increment was then computed for each increment above the constant-cycle fatigue limit. The sum of the cycle ratios for all increments in the loading spectrum above the fatigue limit were then summed to give the cumulative cycle ratio per 1,000 cycles. On this basis, the number of cycles was ascertained for a cumulative cycle ratio of 1.0 and the fatigue life predicted by Miner's theory.

The cumulative cycle ratios for the log-mean fatigue lives, $\overline{N_v}$, for the variable-cycle tests are given in Tables 6 and 7. The corresponding values based on the computed fatigue lives, N_{vc}, are given in Table 8. From these data it is readily evident that the fatigue life of the members was not as great as predicted by Miner's theory, but in most cases was slightly greater than predicted by the analysis of this investigation.

It will be noted that the plot which shows the fatigue lives predicted by the log-distribution method in Fig. 26 is not extended into the region of the fatigue limit of the basic S–N diagram. This is because the spectrum-type fatigue tests of Dolan et al[19] displayed variable-cycle fatigue limits greater than the fatigue limits for the corresponding constant-cycle tests. Therefore, it is probable that if variable-cycle test data had been obtained for the lower stress levels in the present investigation, they too would have displayed a fatigue limit of S_A greater than 21,000 psi which was taken as the fatigue limit in the constant-cycle tests. The predicted cycles to failure for these lower levels would then have been too conservative.

The majority of the specimens tested in this series did not run continuously because of mechanical and electronic difficulties. As these problems arose and were solved, adjustments were made in the equipment and breakdowns became less frequent. However, many of the specimens were run only during normal working hours so that the equipment could be watched closely when in operation. This gave large rest periods to

the specimens. For years rest effects have been considered negligible[27], although recent investigations have provided data which seem to disagree with this earlier data.

An analysis of the running time of the joint specimens of the present tests has been made, and the results are shown in Fig. 28. The percentage of actual running time to the total test time (running time plus resting time) is compared to the percentage of test cycles to the predicted cycles. The curve has been sketched in to show the general trend of the results. The specimens which are plotted at zero time, (B–4, K–1, K–6) were run over the predicted value and then rested several months before testing to failure. Although there is a great deal of scatter in the data, it appears that long periods of rest may increase the fatigue strength of a member.

5. Static Tests

Two joints, specimens S–1 and S–2, which were identical to the fatigue test specimens, were tested in static tension to obtain the general strength characteristics of this type of specimen. Load-slip data were obtained for both tests and are shown by the curves plotted in Fig. 29. These curves appear to have the same general shape as would curves for similar riveted joints.

The plate material for the static specimens and two coupons were taken from adjacent positions in the parent plate, A. The yield point and ultimate strength for these two coupons averaged 44,700 and 67,100 psi, respectively.

Local yielding was noted in the testing of specimen S–1 at a load of 70,000 lb, and general yielding was noted at about 76,000 lb. These loads correspond to an average stress on the net section of 46,000 psi and 50,000 psi, respectively. At a load of 108,900 lb, the fasteners sheared suddenly. After the initial shear failure, new studs were installed, and a tension failure was obtained at the critical net section at a load of 114,900 lb (75,700 psi).

For specimen S–2, local yielding of the center plate was noted at a load of 75,000 lb, and the joint yielded generally at approximately 80,000 lb. At a load of 108,650 lb, this joint also failed suddenly in shear. Again the studs were replaced, and a plate failure occurred through the critical net section at 115,600 lb.

The average ultimate shearing resistance of the studs for the two specimens was 54,800 psi. This is not greatly different from the average ultimate shearing resistance generally obtained for structural steel rivets.

The G/d value (gage divided by hole diameter) for these joints is 5.33; therefore, they would be expected to have an efficiency of about 87 percent according to the G/d method of computing the efficiencies of flat-plate riveted joints[28]. The ultimate loads and actual test efficiencies are given in Table 9. The average test efficiency obtained for the shear failures is about 2 percent below the predicted efficiency, but the tension failure efficiency is about 3 percent greater than the predicted efficiency. This result is similar to that obtained in other tests, in that when initial shear failures occur at loads closely approaching the ultimate strength, there appears to be an increase in the strength of the plate material on subsequent refastening and testing.

F. SUMMARY OF RESULTS

1. Summary of Previous Studies

In general, previous fatigue damage studies can be separated into the following categories:

(1) Studies in which the changes that occur in the fatigue limit due to prestressing at overstresses and understresses were investigated.

(2) Those wherein the effects of prestressing are studied in terms of the change in the number of cycles to failure at a different stress level.

(3) Investigations designed to study fatigue service life by subjecting test specimens to load patterns which are repeated a relatively large number of times before failure occurs.

The findings of studies in the first two categories indicate, in general, that cycling at an overstress for a portion of the fatigue life damages the specimen by causing the fatigue limit after prestressing to be lower than the fatigue limit displayed by the basic S–N diagram. However, there are indications that some cycling at very low overstresses can raise the fatigue limit perceptibly for some materials.

Understressing just below the basic fatigue limit can raise subsequently determined fatigue limits for some materials. In some studies successive increases in the stress level from an initial high understress has led to extremely long lives at final stresses considerably above the initial fatigue limit. This type of manipulation is known as coaxing.

Generally, it has been observed that overstressing tends to reduce the ordinary fatigue life at a subsequently lower overstress, and that it tends to increase the fatigue life at a subsequently higher overstress.

Cumulative damage studies have been directed toward the expression of fatigue damage as a function of the prestress cycle ratios. Miner and some other investigators assumed the fatigue damage was equal to the summation of the cycle ratios, but others have shown that fatigue damage varies in a more complex manner with the total or cumulative cycle ratio. Richart and Newmark proposed that damage might vary with a power of the prestress cycle ratio for a given prestress and test stress. They also emphasized that the order of application of a small number of blocks of different cyclic stresses had a very definite effect on the fatigue life, but that as the number of applications of the pattern of blocks increased the order became less significant.

2. Summary of Present Study

In the present investigation of cumulative damage in the fatigue of structural joints, extensive use has been made of test data from previous fatigue damage studies. In most of these investigations tests were conducted at two or more stress levels on small rotating beam specimens. Rotating-beam tests are relatively easy to conduct, and the cycling rate is usually high; therefore, many investigators have used this type of test to obtain a large number of results in a reasonable period of time.

In the present study an attempt has been made to derive a useful empirical method for estimating the fatigue lives of structural joints when tested under a spectrum-type loading pattern. The method proposed in this study has been derived from the extensive rotating beam test data obtained by other investigators. Data from two studies, in particular, have proved very useful for the present investigation. These data were obtained by Kommers[14] and Dolan, Richart and Work[19].

Kommers obtained new S–N relationships after separate series of identical specimens had been subjected to various cycle ratios of a single high overstress. Thus, the effects of this overstress were demonstrated for other stress levels. In the present study these data were used to demonstrate the changes that are likely to occur in S–N relationships which show the *total* cycles to failure including the cycles of the initial overstress. This was accomplished by merely "adding-in" the cycles of the initial overstress or prestress to show the total cycles to failure.

This "adding-in" of the prestress cycles causes curves for prestressed specimens to "rotate" in a clockwise direction about the value of the prestress on the basic S–N

diagram. The limiting rotation appears to be a vertical line through the point of rotation on the basic S–N curve. This vertical line represents the limit as the prestress cycle ratio approaches unity. Furthermore, a study of this type of plot indicated that the rotation between the basic S–N diagram and the vertical line was approximately proportional to the prestress cycle ratio. Other test data are needed, however, to evaluate this rotation effect further.

Qualitatively, the rotation effect illustrates two of the important findings of previous fatigue damage studies. It indicates that an overstress has a damaging effect on the fatigue life at a subsequently lower overstress, and that it has a healing effect on the fatigue life at a subsequently higher overstress. Quantitatively, it indicates a range of cycles wherein failures should occur for variable-cycle tests if the maximum cyclic stresses are all overstresses.

If all of the maximum cyclic stresses for a given loading pattern are overstresses, then cycling at the major or greatest maximum stress alone would cause failure at N_A cycles as determined from the basic S–N diagram. By cycling at the least or minor maximum cyclic stress alone, failure would occur at N_a cycles. Thus, the interval for any pattern of maximum cyclic stresses can be defined by vertical lines through the major and minor stress levels on the basic S–N diagram. The present study proposes that the number of cycles to failure within this interval is a function of the pattern of maximum cyclic stresses.

A review of the variable-cycle test data obtained by Dolan et al, provided information for an evaluation of β in the relationship,

$$N_v = \frac{N_A{}^{\beta}}{N_a{}^{(\beta-1)}} \qquad (3)$$

In this equation N_v is the fatigue life for a variable-cycle pattern of loading. The distribution coefficient, β, relates the cycles to failure for the variable-cycle loading to the endpoints of the interval, N_A and N_a.

It was also observed from some of Dolan's test data, where the minor maximum cyclic stress was below the initial fatigue limit, that the life interval could be established by extending the basic straight-line S–N diagram to the value of the least or minor maximum cyclic stress. Therefore, to predict the variable-cycle fatigue life by the present method it is only necessary to define the interval of possible failure from an accurately determined S–N relationship and to evaluate the distribution coefficient, β, for the loading pattern at hand.

The distribution coefficient, β, as it is presently evaluated, may be computed as a simple ratio of areas. For simplicity and convenience, a 1,000-cycle envelope of maximum cyclic stresses is plotted on a semi-log basis from 1 cycle to 1,000 cycles. This is done by plotting the difference between the major and minor maximum stresses, S_A and S_a, in order of decreasing magnitude from 1 cycle to 1,000 cycles. Then the ratio of the actual area under this plot to the area of the field on which it is plotted, is the value β. With this information, the variable-cycle fatigue life, N_v, may then be computed.

The method presented herein has been applied to tests conducted by A. M. Freudenthal. This extensive program of tests with various loading patterns shows good agreement with the method.

Sixteen variable-cycle pulsating tension fatigue tests of joint specimens and five of plain plate specimens were conducted for this investigation. For each test the major maximum cyclic stress, S_A, was twice the magnitude of the minor maximum cyclic stress, S_a. A sine wave loading pattern was used in all cases for the variation in the maximum cyclic stresses. The minimum cyclic stress was held constant at 1,000 psi.

For purposes of comparing the predicted variable-cycle fatigue lives of the specimens with the lives determined by tests, the representative (log-mean) fatigue life for all duplicate specimens was considered as the anti-log of the average of the logarithms of the cycles to failure for each test. Also, the variable cycle fatigue lives were computed in accordance with Miner's theory.

Cumulative cycle ratios were determined from the log-mean fatigue lives for each of the stress levels and compared with the values computed by the method presented herein. Of course, the cumulative cycle ratio by Miner's theory is 1.0 in every case.

G. CONCLUSIONS

The results of this study of the data of previous fatigue damage investigations and of the present variable-cycle tests indicate that it is possible to estimate, with reasonable accuracy, the fatigue lives of structural joints subjected to variable-cycle patterns of loading. In order to estimate the variable-cycle fatigue life of a joint by the method outlined herein it is necessary to know the basic constant-cycle S–N relationship and the pattern of maximum cyclic stress variation.

The range of stresses in the variable-cycle load pattern establishes an interval of cycles to failure on the constant-cycle S–N diagram. The number of cycles to failure falls within this interval and is established by the use of a distribution coefficient which accounts for the distribution of stresses within the load pattern.

If it is assumed that the fatigue lives of actual structural joints, which are subjected to more or less random variations of stresses, can be approximated by the repeated application of patterns of loading, wherein the cyclic stresses occur with the same frequency as the service stresses, then it may be possible to apply this method of fatigue life analysis to actual structures.

Because of the small number of tests conducted for this study, it is not possible, at the present time, to make an accurate evaluation of the proposed method for estimating the variable-cycle fatigue lives of structural joints. However, the test results indicate the existence of a relatively good laboratory correlation between the predicted fatigue lives and those obtained by tests.

Another manner of interpreting the data of this variable-cycle study would be the use of an equivalent fatigue strength—the constant-cycle fatigue stress which provides the same fatigue life as the variable-cycle loading. The theory presented herein provides for the test loading, a fatigue life at a given major maximum stress (sine wave pattern and minimum stress of 1,000 psi) which is equal to the fatigue life for an equivalent constant-cycle stress approximately 2,000 psi below the major maximum stress. On the basis of Miner's theory, the equivalent constant-cycle stress would be approximately 4,000 to 5,000 psi below the major maximum stress. Thus, the variation in maximum cyclic stress obtained in railway bridges may be expected to provide a marked increase in life; an increase in life possibly equivalent to a decrease of approximately 2,000–3,000 psi in the maximum stress in constant-cycle loading.

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TABLE 1

COMPARISON OF FREUDENTHAL'S[20] TEST RESULTS ON 75S-T6 ALUMINUM ALLOY WITH COMPUTED RESULTS

Distribution Pattern	Value of β		Difference $\beta_T - \beta_C$	Percent Error
	Test	Computed		
A	0.723	0.673	+0.050	+6.91
B	0.766	0.755	+0.011	+1.44
C	0.582	0.660	-0.078	-13.40
A'	0.531	0.554	-0.023	-4.33
B'	0.642	0.580	+0.062	+9.65
C'	0.508	0.509	-0.001	-0.20
A"	0.794	0.776	+0.018	+2.27
B"	0.812	0.822	-0.010	-1.23
C"	0.677	0.777	-0.100	-14.79
		Total Net Error, percent		-13.68
		Average Net Error, percent		-1.52

TABLE 2

CHARACTERISTICS OF VARIABLE-CYCLE TEST SYSTEM

Fatigue Machine	
Capacity	50,000 lb
Minimum Amplitude of Load Cycle	2,500 lb
Maximum Amplitude of Load Cycle	25,000 lb
Range of Mean Load	2,500 - 47,500 lb.
Operating Frequency	5 Cycles per sec
Weighbar Calibration Constant	44.8 lb per microin per in
Control System	
Maximum Rate of Load Correction*	Approx. 12,000 lb per min
Maximum Programming Rate**	Approx. 20 min
Width of Dead Zone	Approx. 1500 lb
Time Delay Correction	
Time On	1 sec
Time Off	2 sec

* For a steel specimen of 1.75 sq in cross section area.

** For sine wave variation used in present tests.

TABLE 3

AVERAGE MECHANICAL PROPERTIES OF 5/16-IN STRUCTURAL STEEL PLATE FOR TEST SPECIMENS

Plate	Yield* Point, psi	Ultimate Strength, psi	Reduction of Area, per cent	Elongation in 8 in , per cent
A	45,100	66,200	51.7	26.9
B	43,300	66,800	48.6	27.4

* Lower yield point.

TABLE 4

RESULTS OF CONSTANT-CYCLE FATIGUE TESTS

OF JOINT SPECIMENS

Spec. No.	Max.* Cyclic Stress psi	Cycles to Failure, N, 1000's	Log N	$\overline{\text{Log N}}$	$\bar{N}$ 1000's
B-1	32,000	137.6	5.13862		
B-2	32,000	162.5	5.21085		
B-3	32,000	185.4	5.26811		
B-4	32,000	226.7	5.35545		
				5.24326	175.9
C-3	28,000	399.3	5.60130		
C-1	28,000	461.4	5.66408		
C-2	28,000	552.8	5.74257		
				5.66932	467.0
A-4	24,000	1,153.0	6.06183		
A-2	24,000	1,571.1	6.19621		
A-3	24,000	1,612.8	6.20757		
A-1	24,000	1,822.0	6.26055		
				6.18154	1,518.9
E-1	22,000	2,383.9	---	---	---
E-2	22,000	2,389.7	---	---	---
D-1	21,000	4,169.0	---	---	---
D-2	21,000	8,899.9+**	---	---	---
H-1	20,500	8,352.2+	---	---	---
G-1	20,000	11,405.3+	---	---	---
F-1	19,500	11,002.1+	---	---	---

* Stress cycles varied from a minimum tension of 1,000 psi on the net section to a maximum tension.

** + indicates that the specimen did not fail.

TABLE 5

RESULTS OF CONSTANT-CYCLE FATIGUE TESTS

OF PLAIN PLATE SPECIMENS

Spec. No.	Maximum* Cyclic Stress psi	Cycles to Failure, N	Log N	$\overline{\text{Log N}}$	$\bar{N}$
HP-1	32,000	185,700	5.26881		
HP-2		207,000	5.31597		
JP-3		166,200	5.22063		
JPH-7		174,200	5.24105		
JPH-8		328,400-**	5.51640		
JPH-9		147,100	5.16761		
JPH-11		321,700	5.50745	5.31970	208,800
JPH-19	31,000	240,400	5.38093		
JPH-20		274,200	5.43807	5.40950	256,700
JPH-1	30,000	726,300	5.86112		
JPH-5		702,100	5.84640	5.85376	714,100
JPH-3	29,000	503,100	5.70165		
JPH-10		546,000	5.73719	5.71942	524,100
JPH-2	28,000	7,016,400+	6.84611		
JPH-6		930,800	5.96886		
JPH-12		857,700	5.93334		
JPH-13		852,300	5.93059	6.16972	1,478,000
JPH-15	27,000	868,100	5.93857		
JPH-32		802,400	5.90439	5.92148	
JPH-14	26,000	7,125,700+	6.85283	6.85283	7,125,700
JPH-29	25,000	1,221,000	6.08672		
JPH-30		760,500	5.88110	5.98391	963,600
HP-3	24,000	1,949,100	6.28983		
HP-4		1,165,600	6.06655		
JP-1		1,088,100	6.03667		
JP-2		573,900	5.75884		
JP-4		4,748,800	6.67651		
JPH-4		1,252,500+	6.09778	6.15436	1,427,000

* Stress cycles varied from a minimum tension of 1,000 psi on the net section to a maximum tension.

** - indicates specimen had failed but micro-switch did not shut off the machine. + indicates that the specimen did not fail.

TABLE 6

RESULTS OF VARIABLE-CYCLE FATIGUE TESTS OF JOINT SPECIMENS

Spec. No.	S_A*, Major Maximum Cyclic Stress, psi	S_a*, Minor Maximum Cyclic Stress, psi	Test Cycles To Failure, N_{V_T}	Log N_V	$\overline{\text{Log } N_V}$	$\overline{N_V}$	Test, Distribution Coefficient, β_T*	Test, Cumulative Cycle Ratio
K-4	24,000	12,000	5,919,000**	6.77225				
L-3	24,000	12,000	1,925,400	6.28443				
L-6	24,000	12,000	3,913,000**	6.59251				
					6.54973	3,546,000	0.8309	0.614
K-5	28,000	14,000	746,400	5.87297				
L-2	28,000	14,000	516,400	5.71299				
L-4	28,000	14,000	1,150,300	6.06070				
					5.88222	762,500	0.9078	0.465
B-3***	30,000	15,000	555,200	---	---	---		
E-2	30,000	15,000	755,600**	5.87829				
E-3	30,000	15,000	567,700**	5.75412				
G-3	30,000	15,000	834,300**	5.92132				
					5.85124	710,000	0.8222	0.733
B-4	32,000	16,000	733,000**	5.86510				
E-1	32,000	16,000	302,700	5.48101				
K-1	32,000	16,000	799,100**	5.90260				
K-3	32,000	16,000	493,900	5.69364				
K-6	32,000	16,000	615,300**	5.78909				
X-2	32,000	16,000	279,600	5.44654				
					5.69633	497,000	0.7986	0.840

* Maximum cyclic stresses varied as a sine wave between S_A and S_a. Pattern was repeated every 9,000 cycles. Tests were begun at S_a. The minimum cyclic stress was held constant at 1,000 psi.

** Portions of test pattern irregular. Maximum change in number of cycles 3%.

*** Failed in upper pull head.

TABLE 7

RESULTS OF VARIABLE-CYCLE FATIGUE TESTS OF PLAIN PLATE SPECIMENS

Spec. No.	S_A*, Major Maximum Cyclic Stress, psi	S_a*, Minor Maximum Cyclic Stress, psi	Test Cycles To Failure, N_{V_T}	Log N_v	$\overline{\text{Log } N_v}$	$\overline{N_v}$	Test, Distribution Coefficient, β_T*	Test, Cumulative Cycle Ratio
JPH-16	32,000	16,000	850,800**	5.92983				
JPH-18	32,000	16,000	512,700**	5.70986				
JPH-21	32,000	16,000	540,400	5.73272				
JPH-28	32,000	16,000	754,800	5.87783				
JPH-34	32,000	16,000	936,300**	5.97142				
					5.84433	698,800	0.7322	0.566

* Maximum cyclic stresses varied as a sine wave between S_A and S_a. Pattern was repeated every 9,000 cycles. Tests were begun at S_a. The minimum cyclic stress was held constant at 1,000 psi.

** Portions of test pattern irregular. Maximum change in number of cycles 3%.

TABLE 8

PREDICTED RESULTS FOR VARIABLE-CYCLE FATIGUE TESTS

Type	S_A, Major Maximum Cyclic Stress, psi	S_a, Minor Maximum Cyclic Stress, psi	Computed,* Cycles to Failure, N_{V_c}	Computed,** Cycles to Failure, Miner's Theory	Computed, Cumulative Cycle Ratio to Failure	$\overline{N_v}/N_{V_c}$	β_T/β_c
Joint Specimens	24,000	12,000	2,487,000	5,779,700	0.431	1.426	0.923
	28,000	14,000	793,800	1,641,100	0.484	0.960	1.009
	30,000	15,000	476,200	968,200	0.492	1.491	0.914
	32,000	16,000	295,200	591,600	0.499	1.684	0.887
Plain Plate	32,000	16,000	447,100	1,234,000	0.362	1.563	0.814

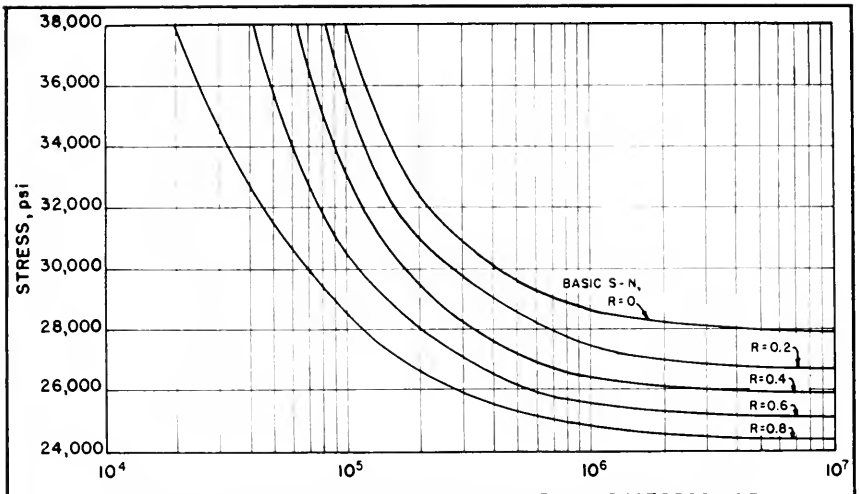
* Based on S-N relationship, $S = 163{,}500/N^{0.135}$ for joints and $S = 207{,}700/N^{0.149}$ for plain plate specimens, and a computed distribution coefficient, $\beta_c = 0.90$ for a sine wave variation of maximum cyclic stresses.

** Based on cumulative cycle ratio of 1.0.

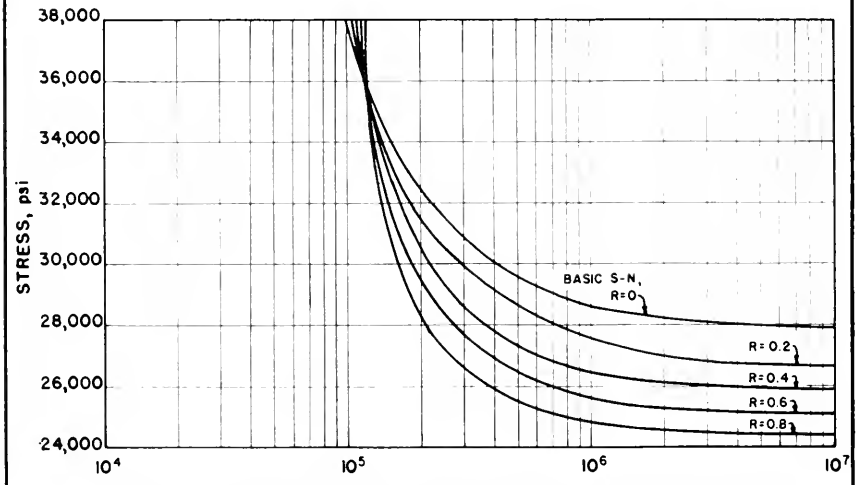
TABLE 9

ULTIMATE STRENGTHS AND EFFICIENCIES OF JOINT SPECIMENS

Specimen	First Loading, Shear Failures		Second Loading Tension Failures	
	Ultimate Load, lb	Test Efficiency, per cent	Ultimate Load, lb	Test Efficiency per cent
S-1	108,900	85.5	114,900	90.0
S-2	108,650	84.8	115,600	90.3

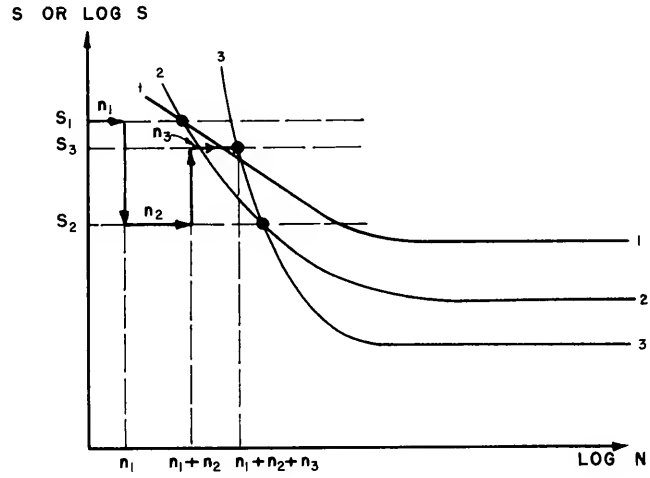


CYCLES TO FAILURE AFTER CYCLING AT A PRESTRESS OF 36,000 psi FOR VARIOUS CYCLE RATIOS, R, OF THE PRESTRESS.



CYCLES TO FAILURE INCLUDING CYCLES AT A PRESTRESS OF 36,000 psi FOR VARIOUS CYCLE RATIOS, R, OF THE PRESTRESS.

FIG. 1 RESULTS FOR ROTATING BEAM TESTS OF SAE 1020 STEEL, KOMMERS, 1945, (14)



CURVE 1-1 BASIC S-N CURVE
CURVE 2-2 CURVE INDICATING TOTAL CYCLES TO FAILURE INCLUDING n_1 CYCLES AT S_1.
CURVE 3-3 CURVE INDICATING TOTAL CYCLES TO FAILURE INCLUDING n_1 CYCLES AT S_1 AND n_2 CYCLES AT S_2.

FIG. 2 DIAGRAMS ILLUSTRATING HOW TOTAL CYCLES TO FAILURE MAY VARY WITH THE PRESTRESS.

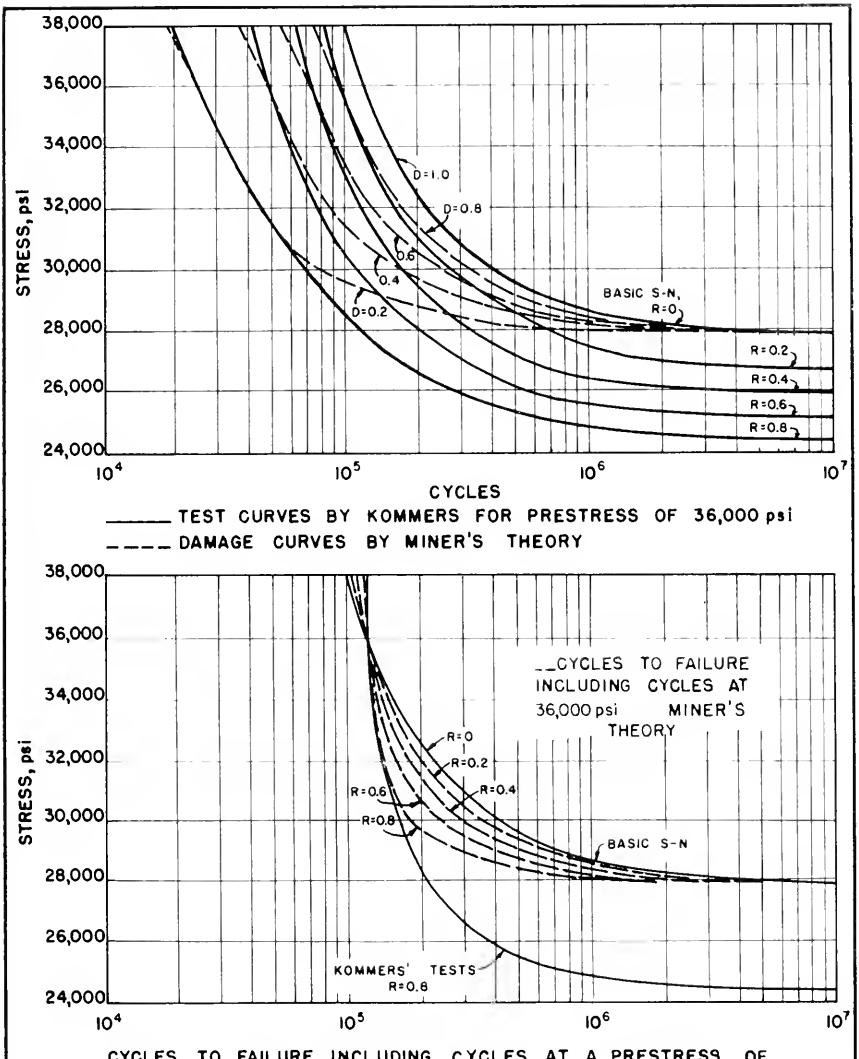


FIG. 3 COMPARISON OF MINER'S THEORY WITH TEST RESULTS FOR SAE 1020 STEEL, KOMMERS, 1945, (14)

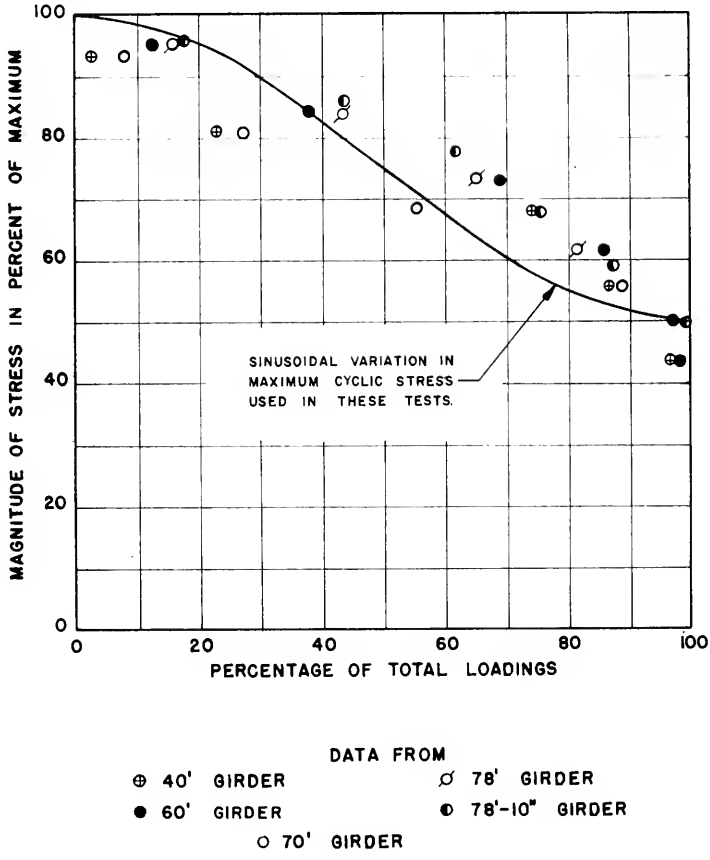


FIG. 4 FREQUENCY DISTRIBUTION OF MAXIMUM STRESSES OBTAINED FROM AAR TESTS.

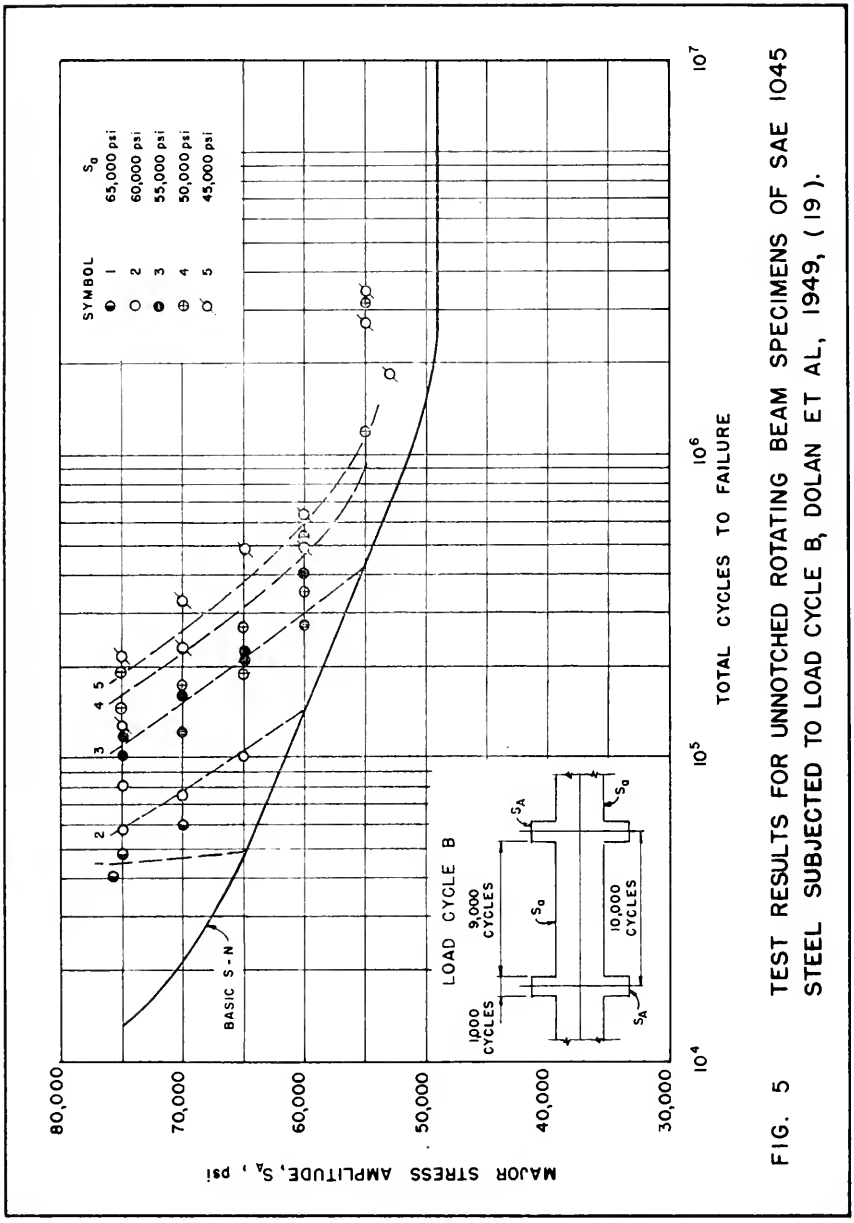


FIG. 5 TEST RESULTS FOR UNNOTCHED ROTATING BEAM SPECIMENS OF SAE 1045 STEEL SUBJECTED TO LOAD CYCLE B, DOLAN ET AL, 1949, (19).

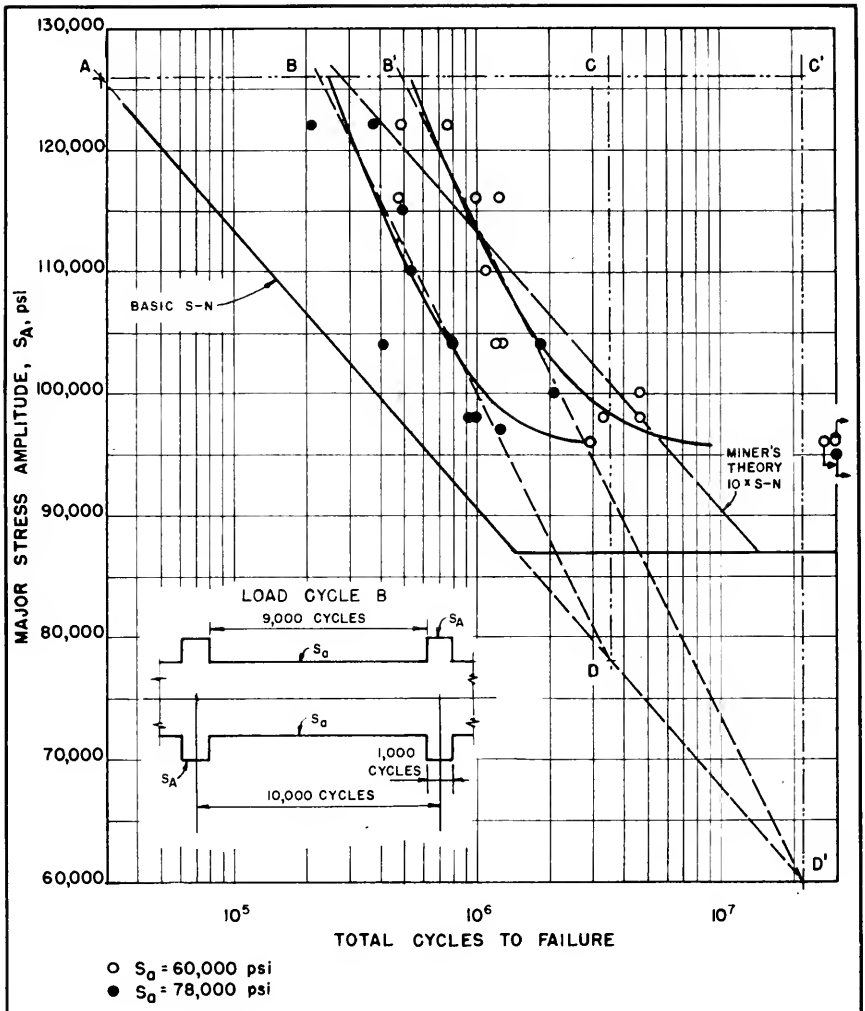


FIG. 6 TEST RESULTS FOR UNNOTCHED ROTATING BEAM SPECIMENS OF SAE 4340 STEEL FOR LOAD CYCLE B, DOLAN ET AL, 1949, (19)

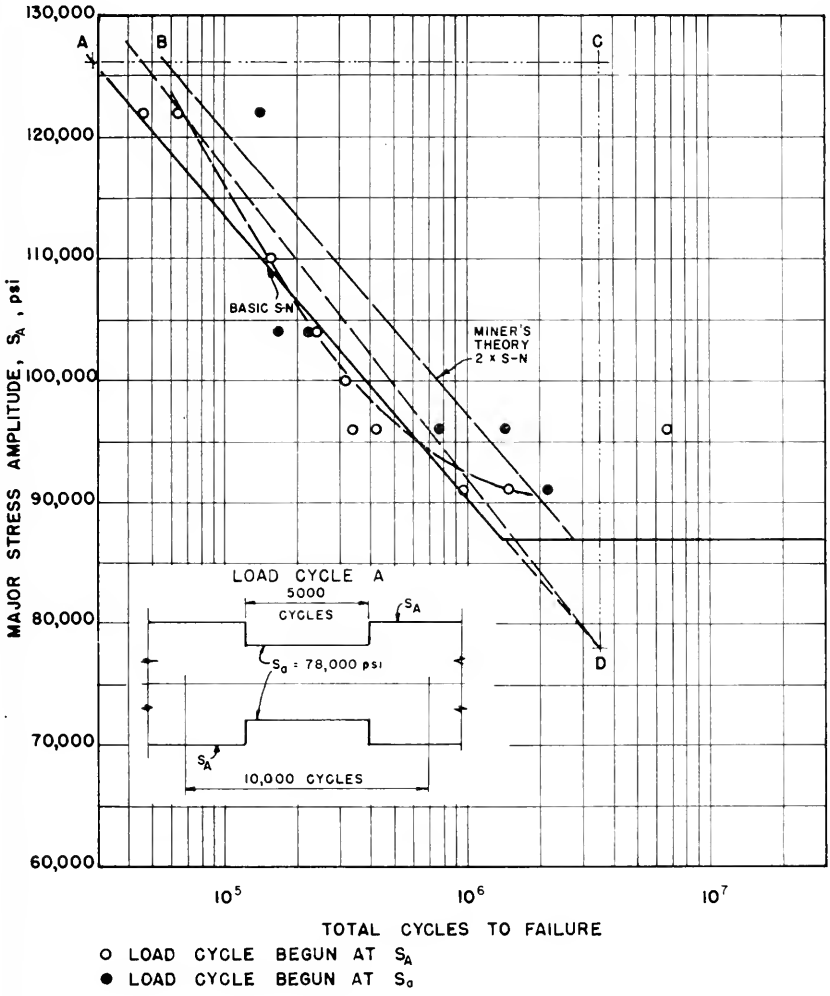
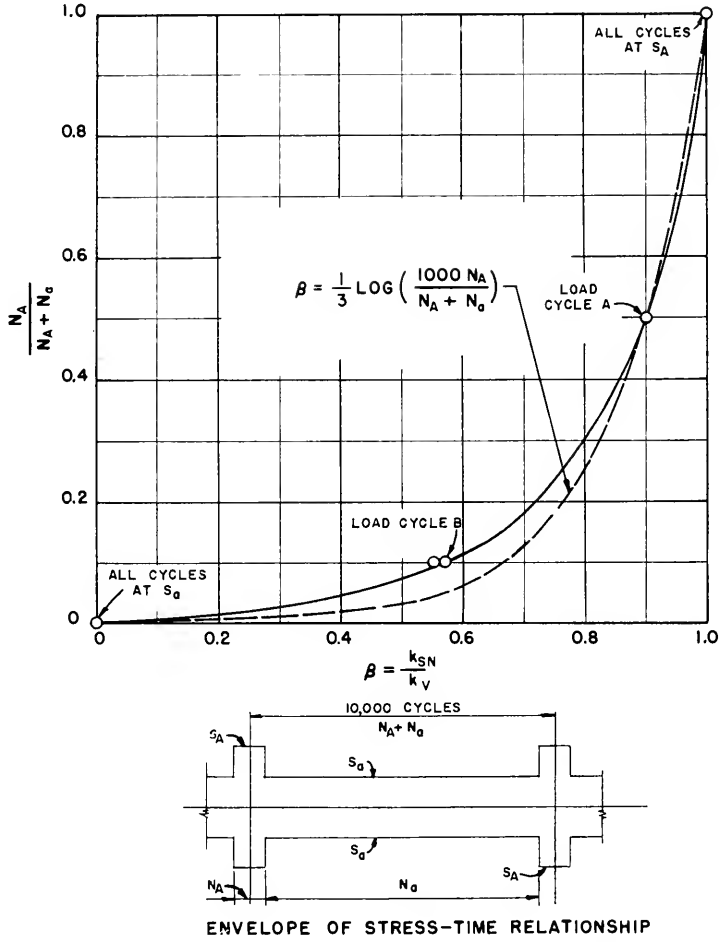


FIG. 7 TEST RESULTS FOR UNNOTCHED ROTATING BEAM SPECIMENS OF SAE 4340 STEEL WITH A MINOR STRESS AMPLITUDE OF 78,000 psi FOR LOAD CYCLE A, DOLAN ET AL, 1949, (19)



k_{SN} = SLOPE OF S-N DIAGRAM
k_V = SLOPE OF VARIABLE CYCLE DIAGRAM

FIG. 8 VARIATION OF DISTRIBUTION COEFFICIENT β, FOR LOADING SPECTRUMS OF TWO STRESS LEVELS, FROM TESTS OF DOLAN ET AL, 1949, (19)

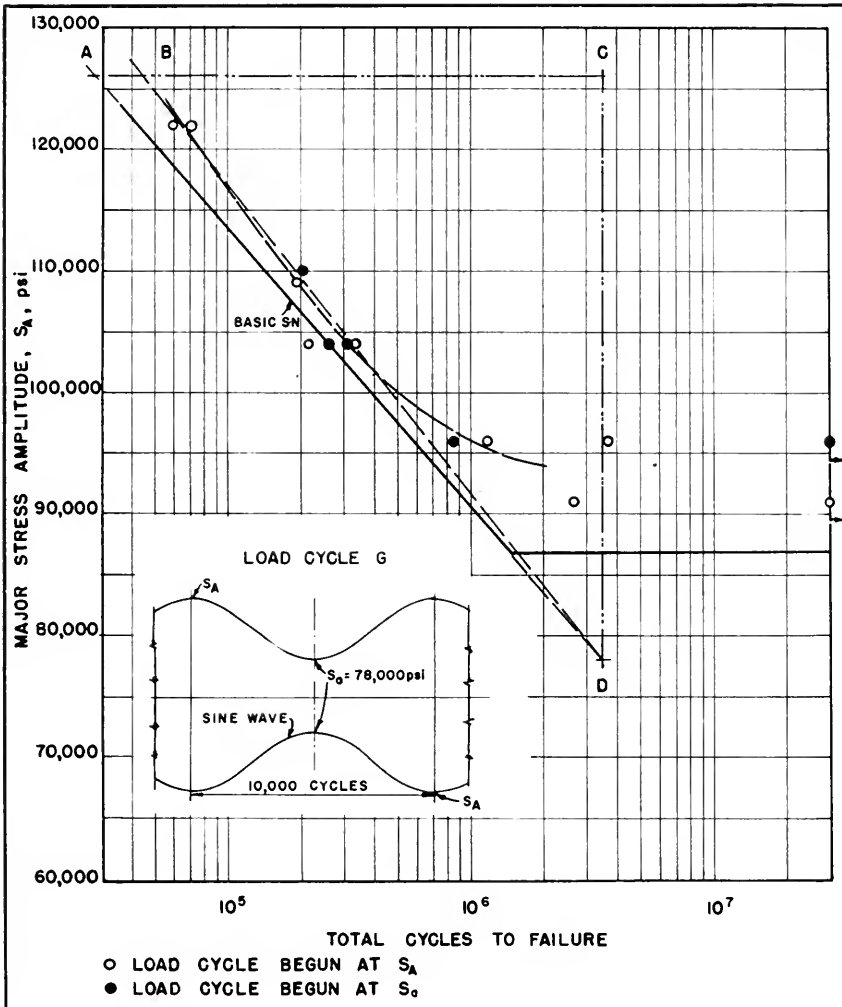


FIG. 9 TEST RESULTS FOR UNNOTCHED ROTATING BEAM SPECIMENS OF SAE 4340 STEEL WITH A MINOR STRESS AMPLITUDE OF 78,000psi FOR LOAD CYCLE G, DOLAN ET AL, 1949, (19).

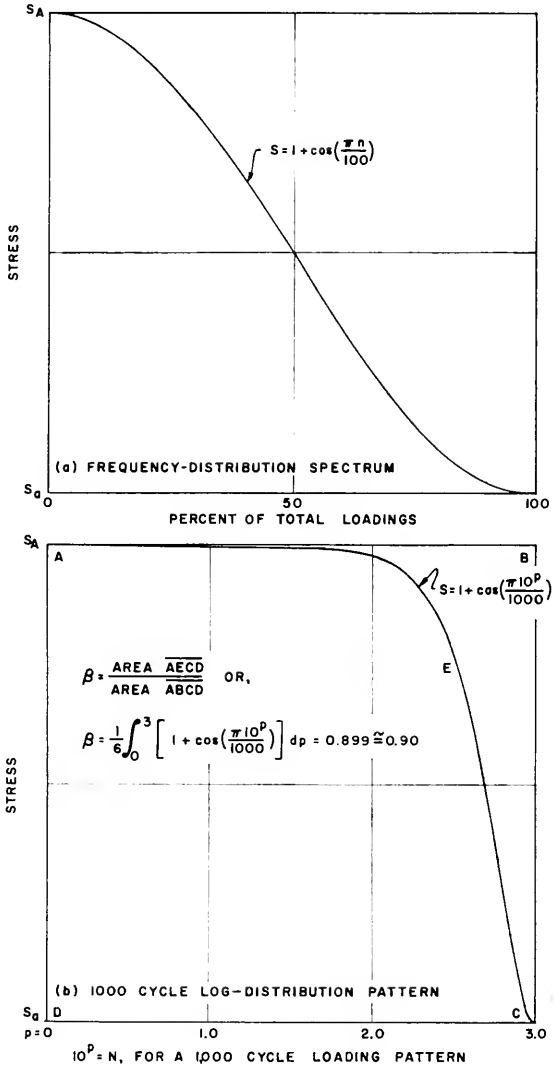


FIG. 10 FREQUENCY DISTRIBUTION AND LOG-DISTRIBUTION DIAGRAMS FOR A SINE WAVE LOADING SPECTRUM

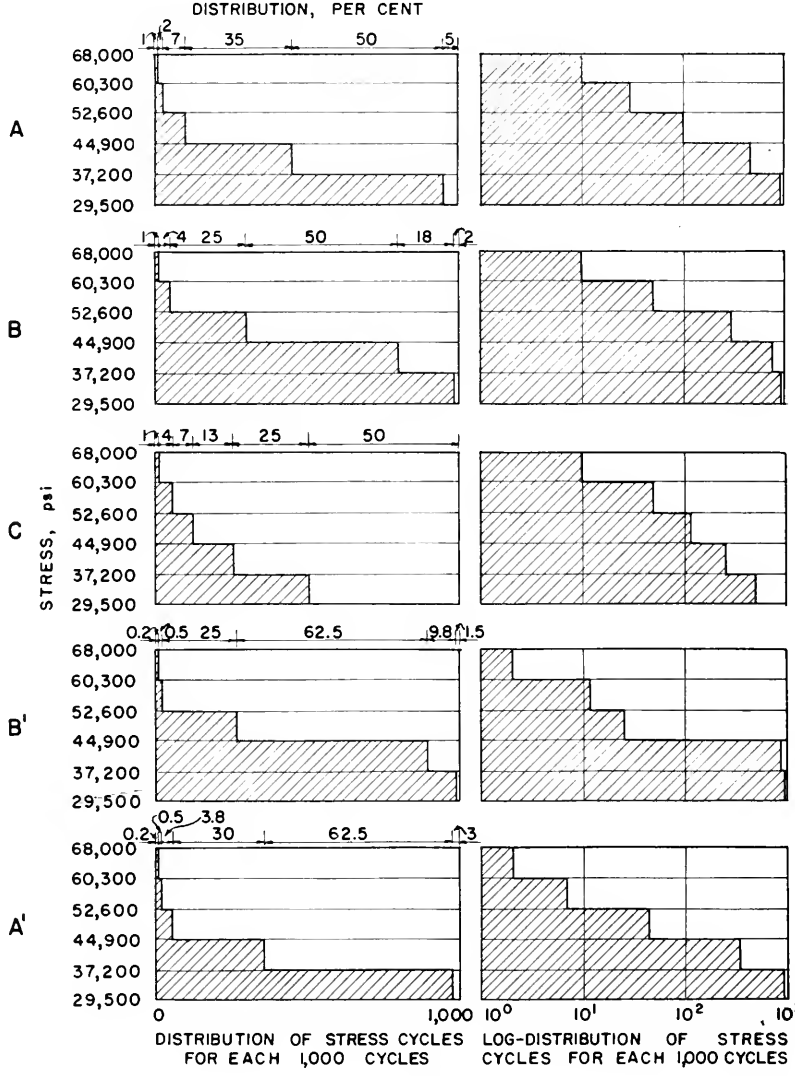


FIG. 11 DISTRIBUTION PATTERNS USED BY FREUDENTHAL FOR TESTS ON 75S-T6 ALUMINUM ALLOY AND DERIVED 3-CYCLE LOG-DISTRIBUTION PATTERNS.

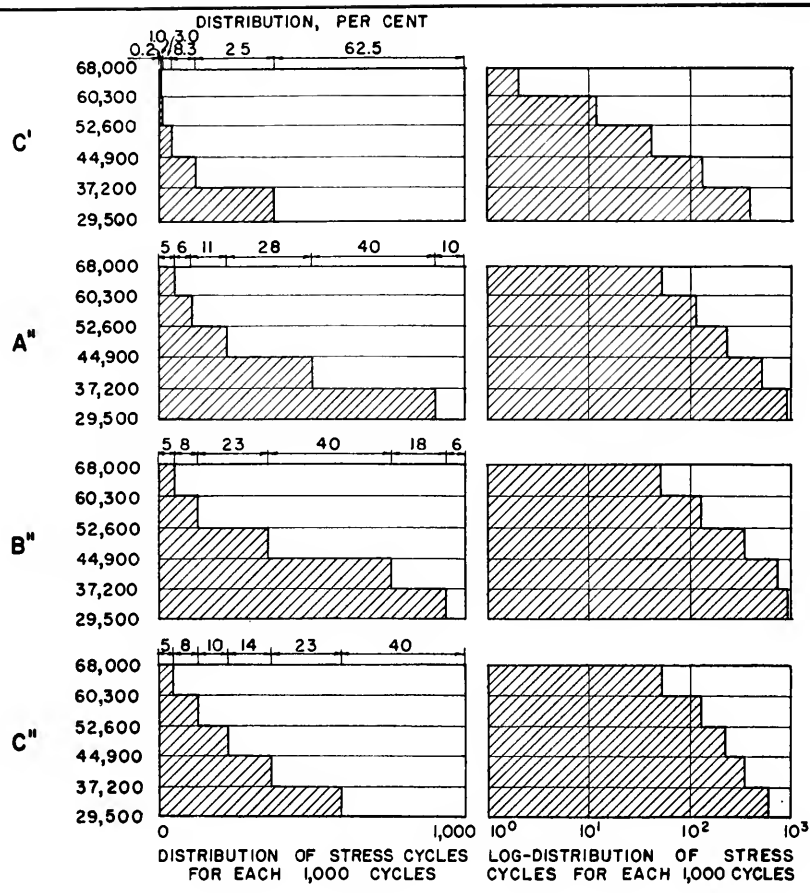


FIG. 12 DISTRIBUTION PATTERNS USED BY FREUDENTHAL FOR TESTS ON 75S-T6 ALUMINUM ALLOY AND DERIVED 3-CYCLE LOG-DISTRIBUTION PATTERNS.

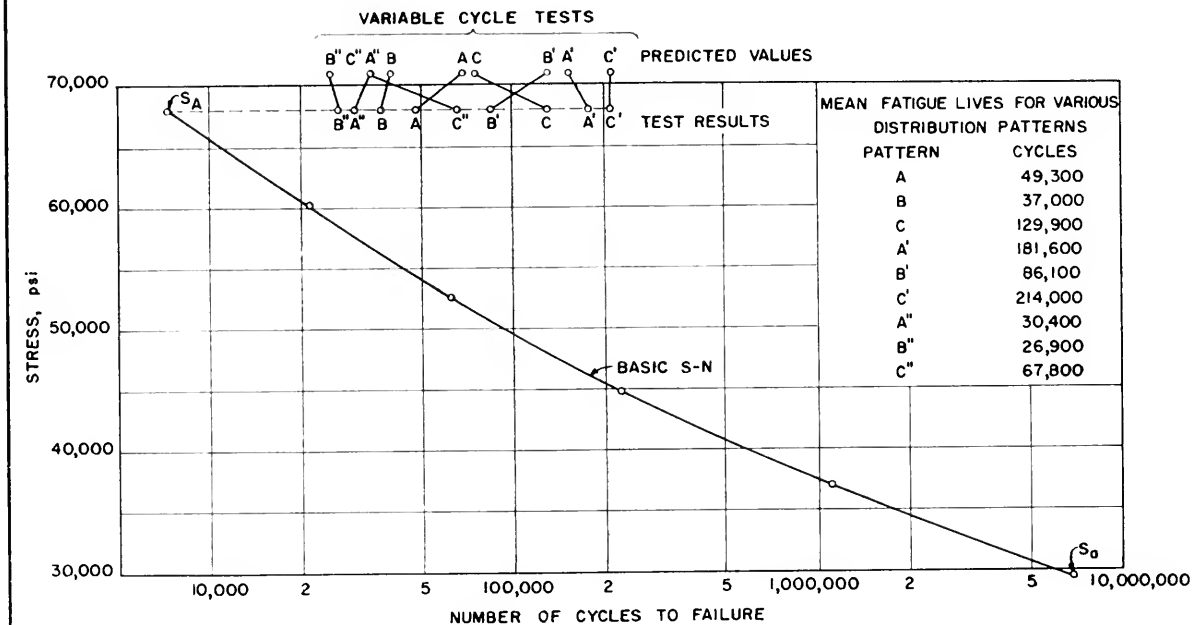
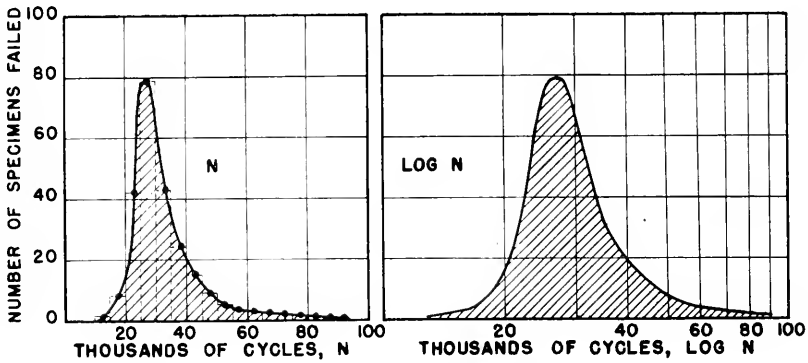
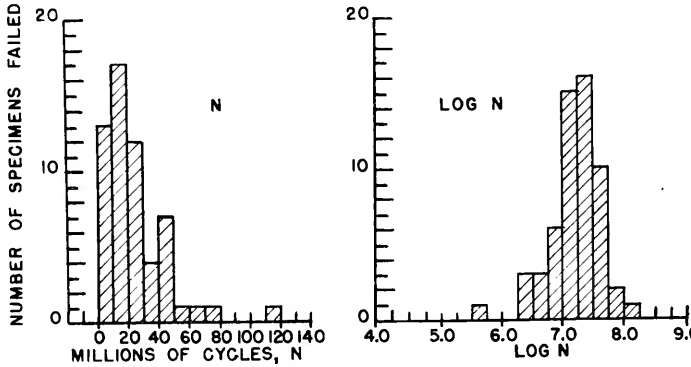


FIG. 13 FREUDENTHAL'S TESTS ON ROTATING BEAM SPECIMENS OF 75S-T6 ALUMINUM ALLOY (THESE DATA REPRESENT THE RESULTS OF 300 FATIGUE TESTS)



DISTRIBUTION OF FINITE FATIGUE LIFE FOR 235 SPECIMENS OF MILD STEEL (GERMAN ST. 37) TESTED IN REVERSED BENDING AT 45,500 psi, MÜLLER-STOCK ET AL, 1930, (13).



DISTRIBUTION OF FINITE FATIGUE LIFE FOR 57 SMALL SPECIMENS OF 75S-T ALUMINUM ALLOY TESTED IN REVERSED BENDING AT 30,000 psi, SINCLAIR AND DOLAN, 1949, (21).

FIG. 14 DISTRIBUTIONS FOR FATIGUE FAILURES.

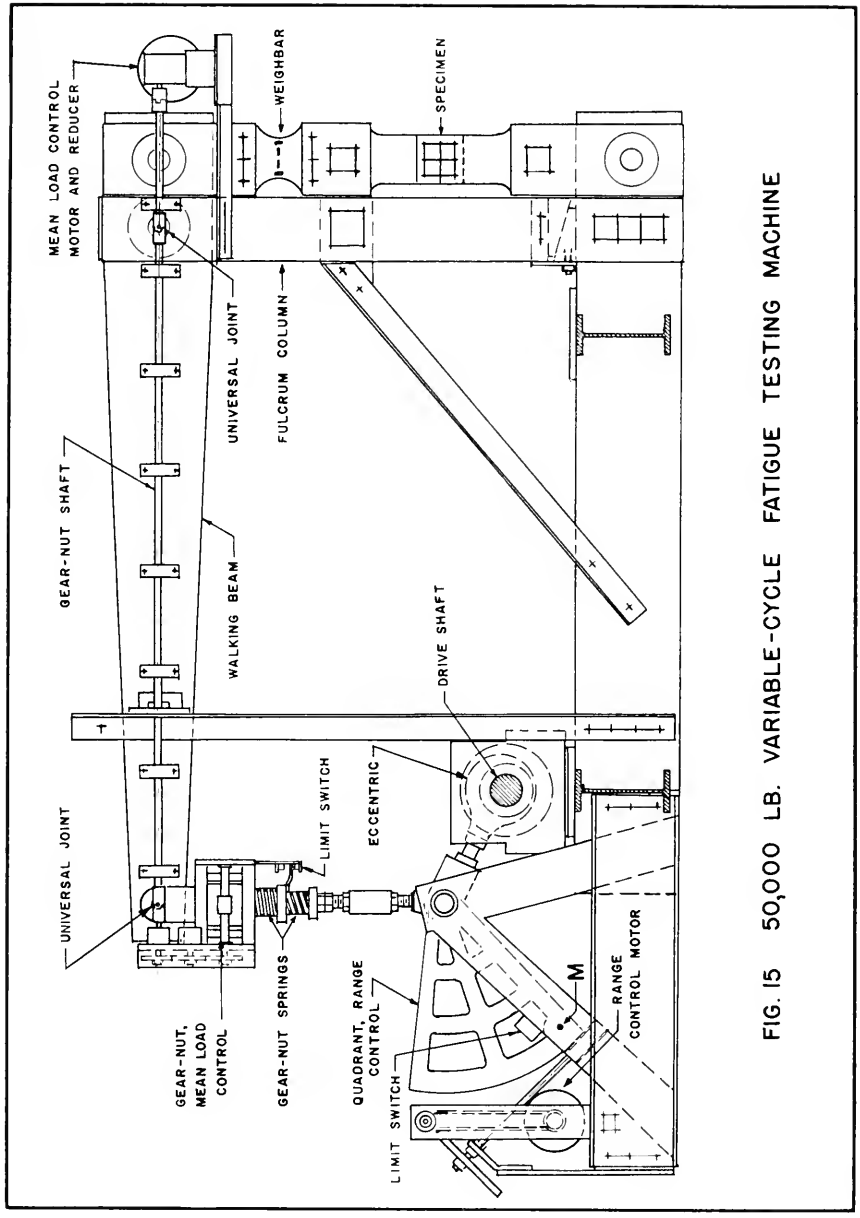
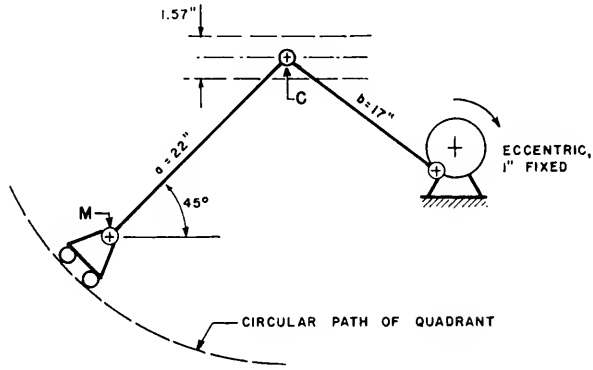
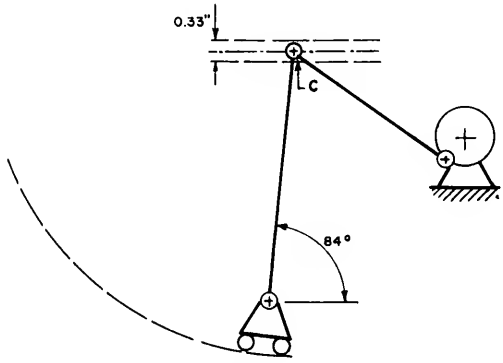


FIG. 15 50,000 LB. VARIABLE-CYCLE FATIGUE TESTING MACHINE

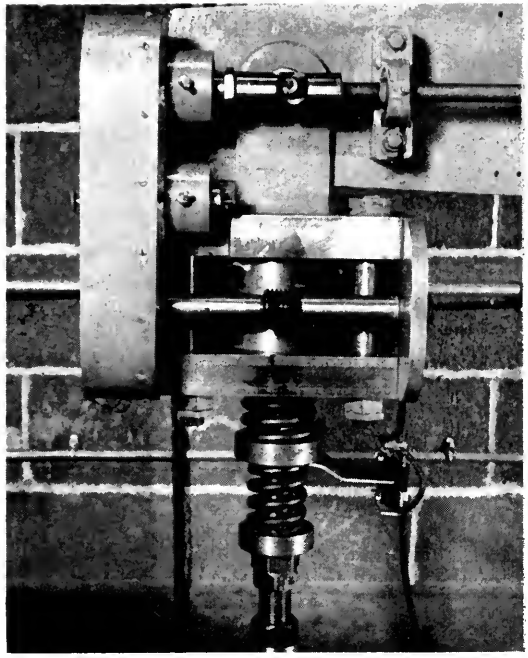


(a) POSITION OF LINKAGE ARM "a" FOR MAXIMUM RANGE

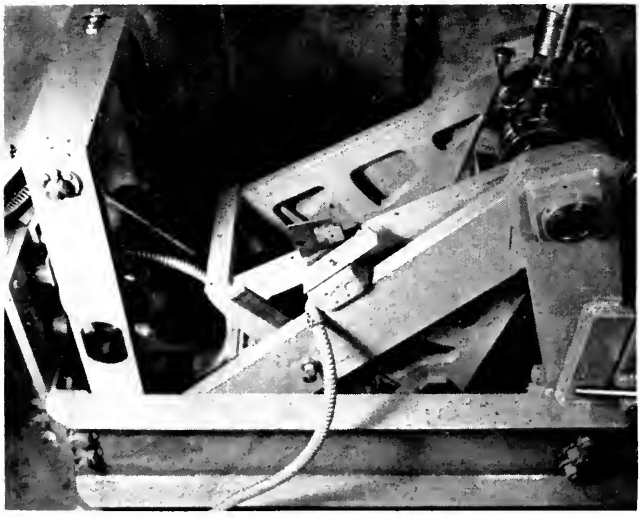


(b) POSITION OF LINKAGE ARM "a" FOR MINIMUM RANGE

FIG. 16 SCHEMATIC DIAGRAMS OF LINKAGE MECHANISM FOR RANGE CONTROL



(a) Gear-nut mean load control.



(b) Quadrant, range control.

Fig. 17—Views of control mechanisms for variable-cycle fatigue testing machine.

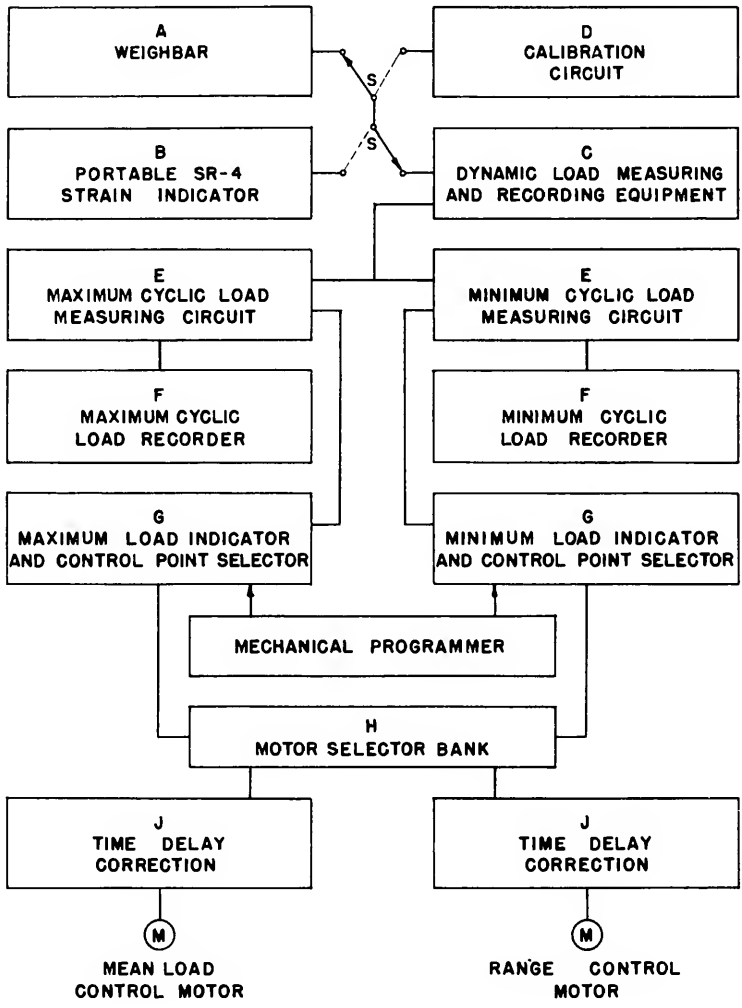


FIG. 18 BLOCK DIAGRAM FOR ELECTRICAL LOAD CONTROL AND MEASUREMENT SYSTEM

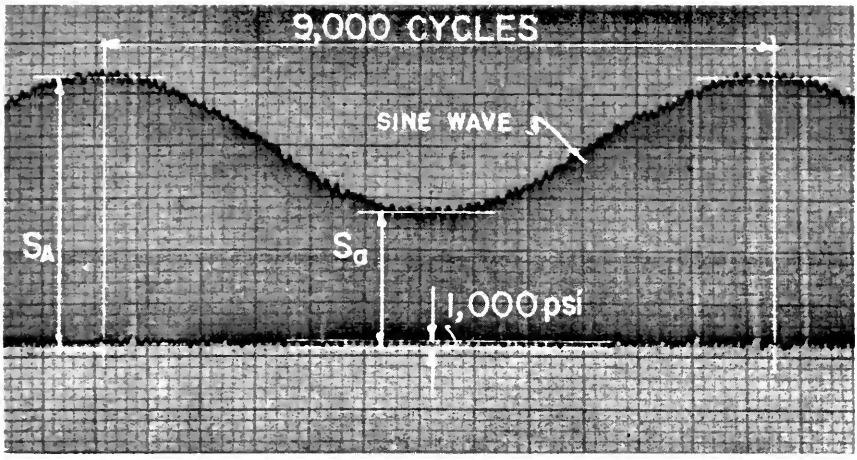


Fig. 19—Sample record of load pattern for present test series.

Fig. 20—View of load control and recording equipment.

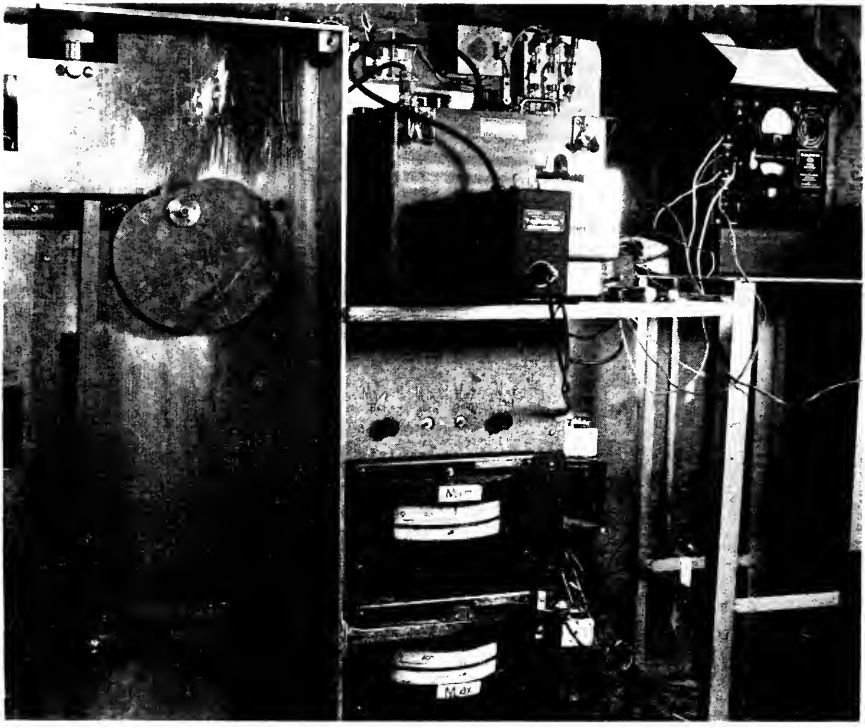
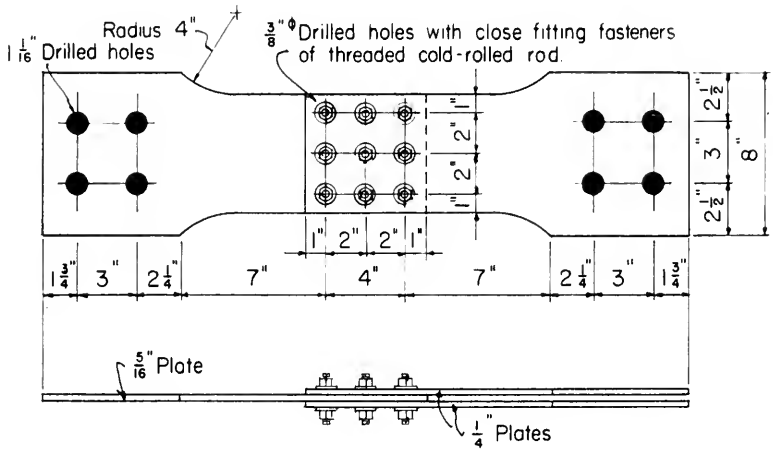
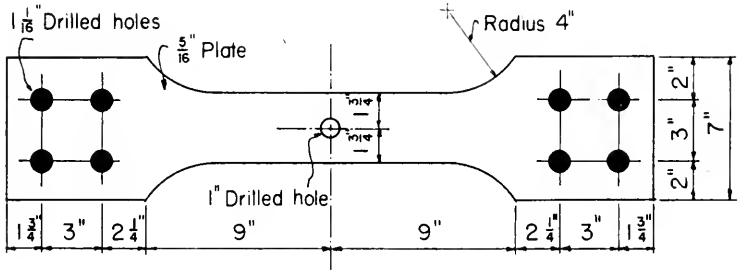


Fig. 21—View of programming unit.



JOINT SPECIMENS



PLAIN PLATE SPECIMENS

FIG. 22 DETAILS OF SPECIMENS

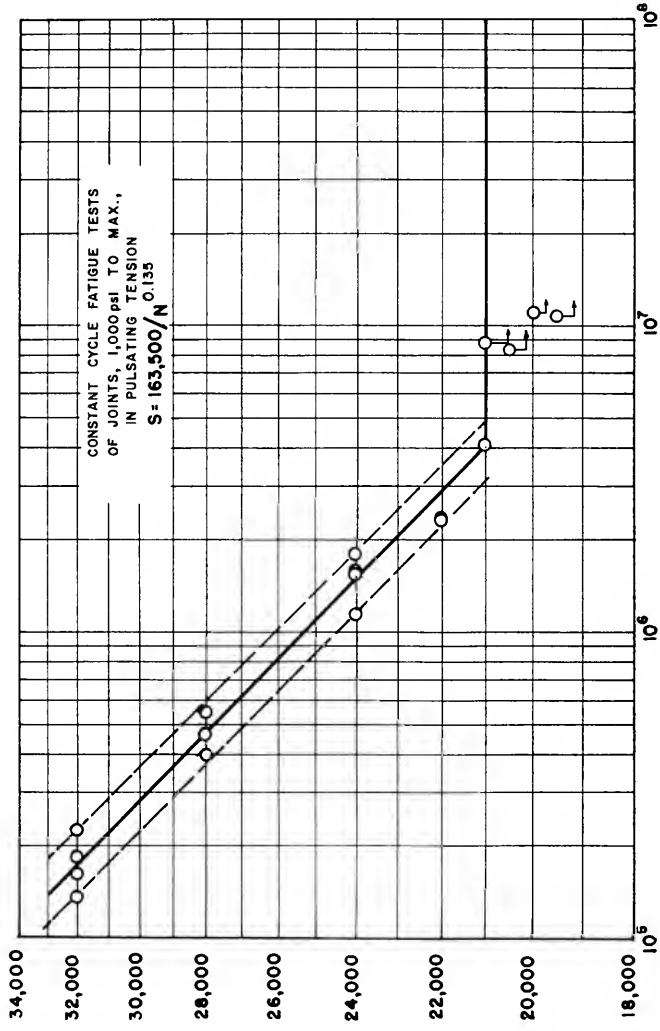


FIG. 23 S-N DIAGRAM FOR JOINT SPECIMENS, CONSTANT-CYCLE TESTS

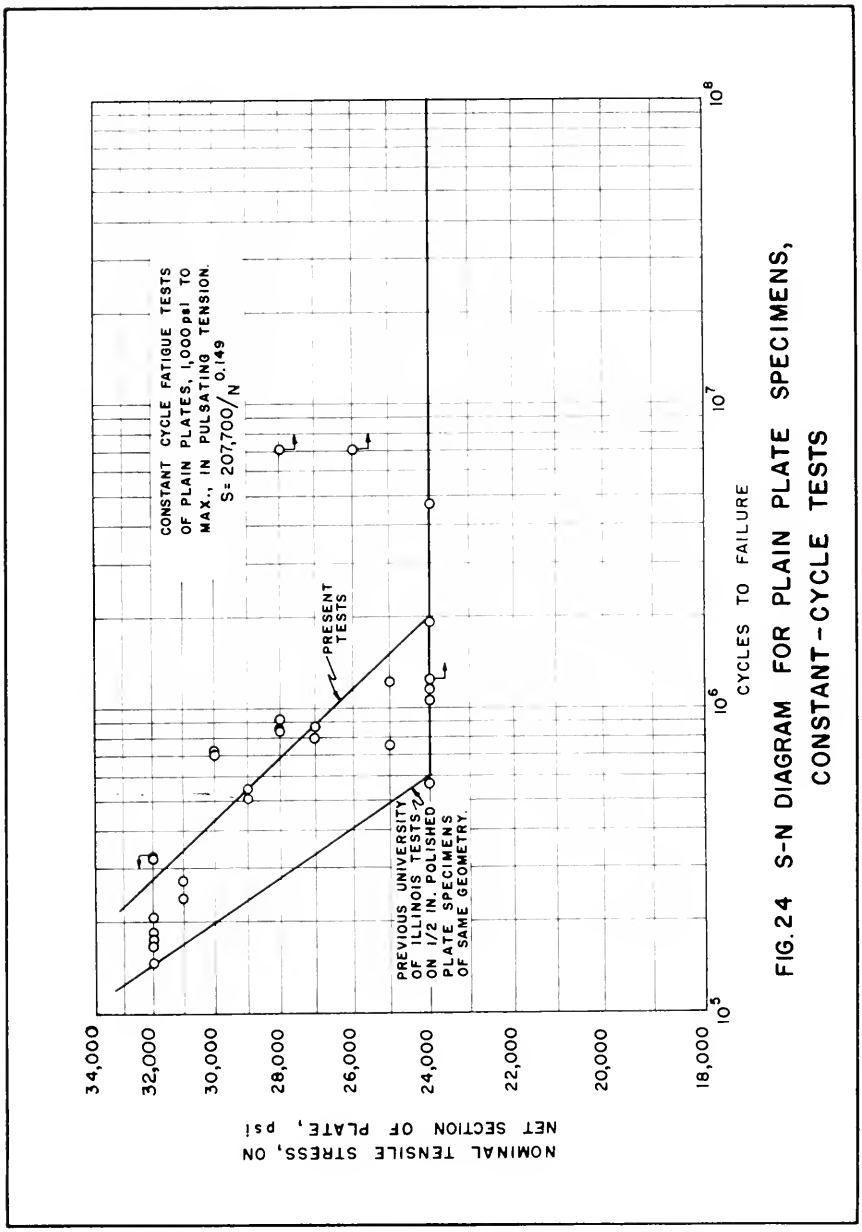


FIG. 24 S-N DIAGRAM FOR PLAIN PLATE SPECIMENS, CONSTANT-CYCLE TESTS

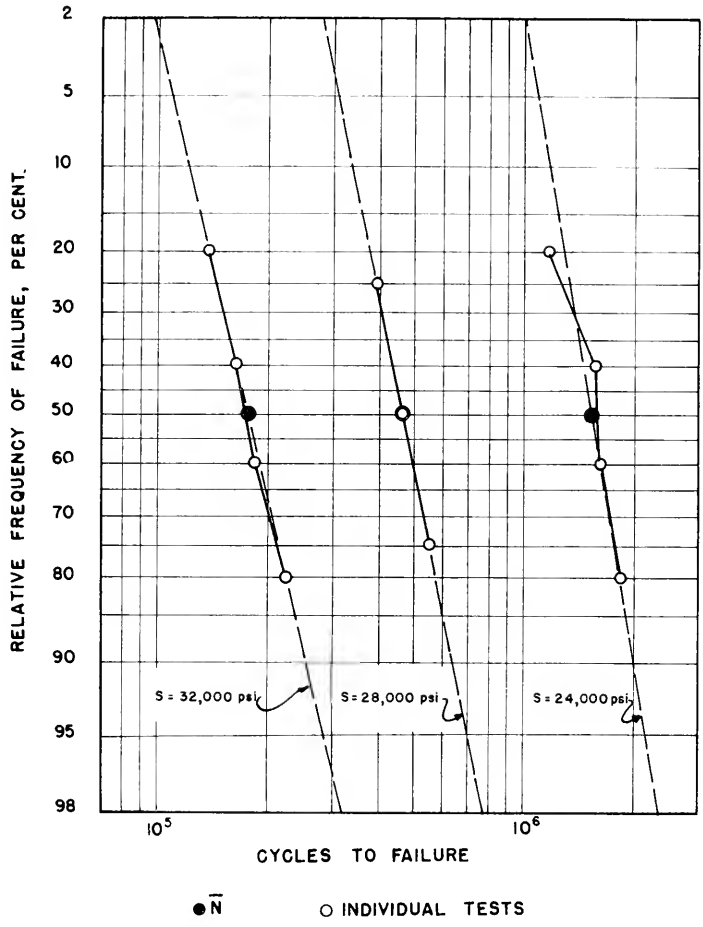


FIG. 25 LOG-NORMAL PROBABILITY DIAGRAMS FOR CONTANT-CYCLE TESTS OF JOINT SPECIMENS

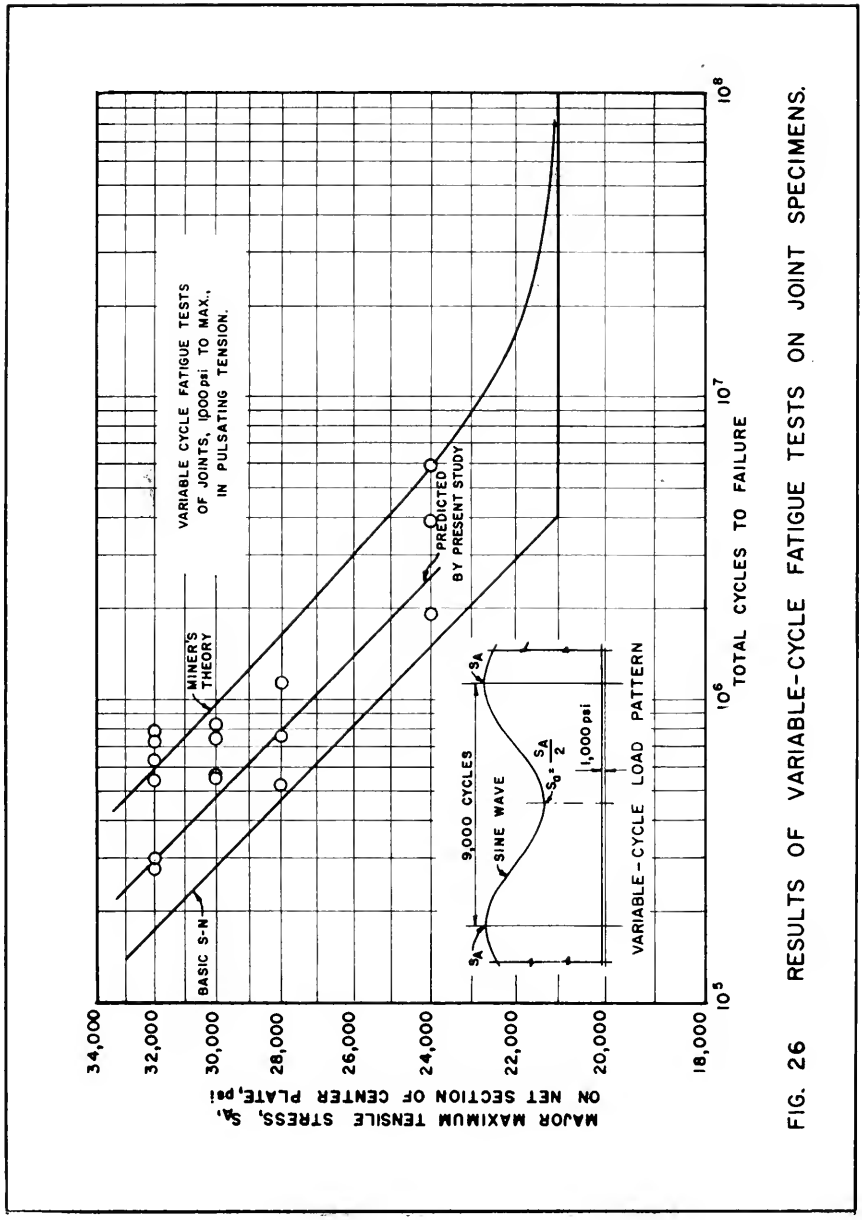


FIG. 26 RESULTS OF VARIABLE-CYCLE FATIGUE TESTS ON JOINT SPECIMENS.

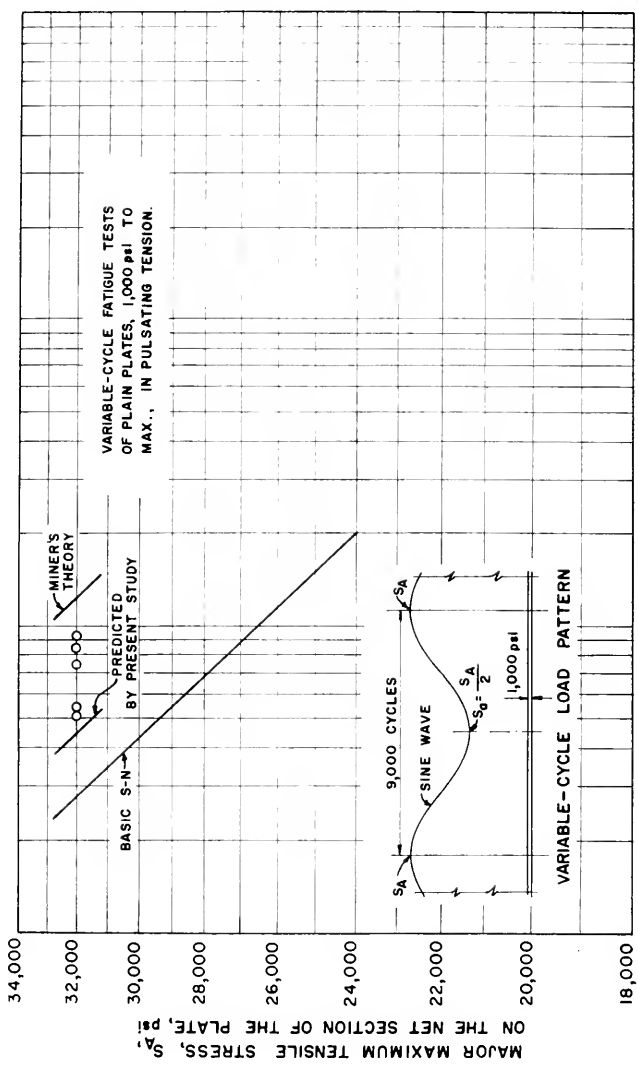


FIG. 27 RESULTS OF VARIABLE-CYCLE FATIGUE TESTS ON PLAIN PLATE SPECIMENS.

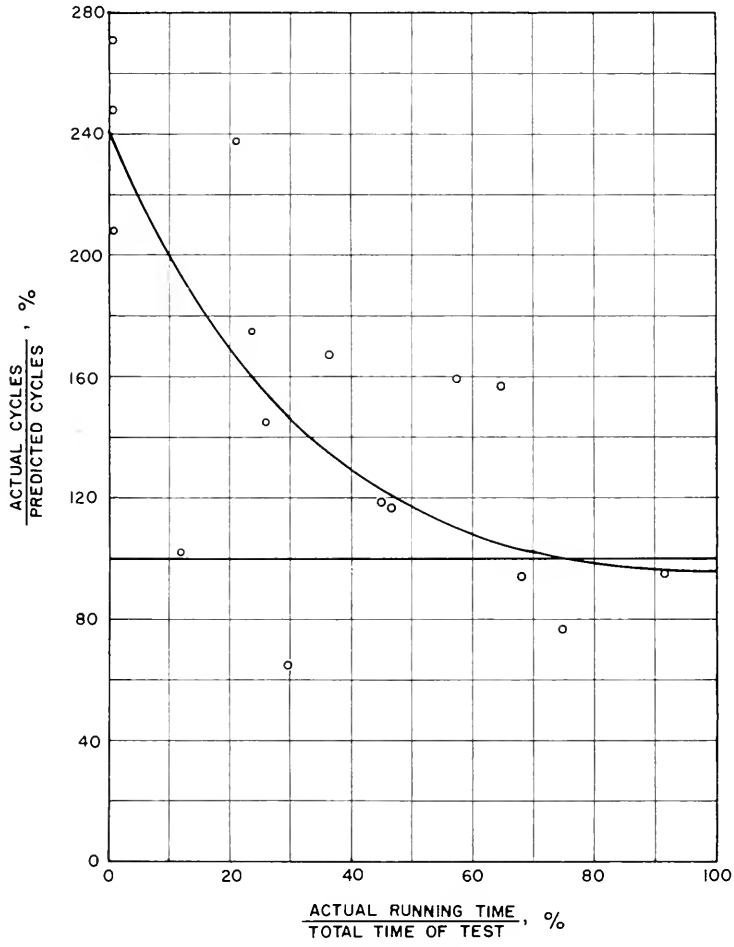


FIG. 28 COMPARISON OF TEST CYCLES WITH TIME FOR TESTING

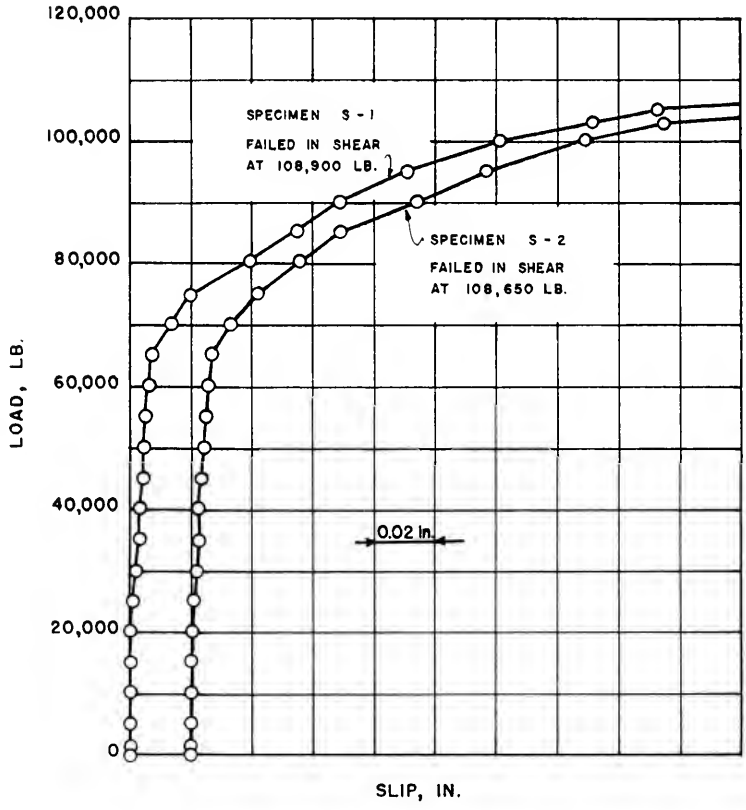


FIG. 29 AVERAGE LOAD-SLIP CURVES FOR SLIP AT FIRST ROW FASTENERS, STATIC TESTS

Advance Report of Committee 3—Ties

Report on Assignment 4

Tie Renewals and Costs per Mile of Maintained Track

L. W. Kistler (chairman, subcommittee), R. W. Cook, W. L. Kahler, C. M. Long, J. W. Neikirk, H. B. Orr, C. A. Peebles.

The annual statistics compiled by the Bureau of Railway Economics, AAR, presenting information on cross tie renewals and cost data for 1957, are shown in Tables A and B.

These statistics realistically reflect the reduced car loadings of the Class I roads of the United States for that year. The 1957 total of 21,525,233 new cross ties inserted in track was the lowest in more than 50 years and represents a reduction of 1,724,216 from 1956, or 7.42 percent. Equated gross ton miles per mile of track was 241,000, or 3.54 percent less than in 1956, and all regions except the Pocahontas showed decreases ranging from 2.62 to 6.25 percent. The Pocahontas Region inserted 5.8 percent more ties and had an increase of 1.51 percent in equated gross ton miles.

This reduction resulted in unusually low insertions per mile of maintained track, the low being 46, with a 5-year average of 50.8 for the New England Region, and the high 88, with a 5-year average of 102.2 for the Southwestern Region. The United States insertions per mile were 67, and the 5-year average 74.2, both all-time lows.

The committee's 1952 report on 1951 statistics stated "for the first time in the history of the American railroads, the 5-year average tie renewals per mile of maintained track is below 100." Now, only 6 years later, it should be of much interest to management that not only has the 5-year average dropped to 74.2, but the 10-year average is only 84.3. Based on 3018 ties per mile, the latter insertion figure indicates an average tie life of 35.80 years.

Again a note of caution is advised in trying to interpret these statistics; there are so many factors and variables which must be given consideration that it is particularly difficult, if not impossible, to make conclusive comparisons among the individual carriers.

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NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class 1 roads in the United States and large Canadian roads, by years, and for the average of five years 1953 to 1957, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1953	1954	1955	1956	1957	5 year average	1953	1954	1955	1956	1957	5 year average	1953	1954	1955	1956	1957	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	111	115	99	130	147	120	$304	$339	$275	$384	$422	$345	3.84	3.97	3.44	4.50	5.09	4.17
Boston & Maine	64	57	23	28	22	39	228	222	89	107	85	146	2.17	1.93	0.78	0.95	0.75	1.32
Canadian Pacific (Lines in Me.)	90	71	52	73	70	71	319	264	198	270	261	262	3.10	2.45	1.80	2.50	2.39	2.45
Central Vermont	63	75	75	90	96	80	263	338	339	405	463	362	2.11	2.52	2.52	3.04	3.22	2.68
Maine Central	85	106	96	84	51	84	302	361	330	284	186	293	2.84	3.55	3.20	2.81	1.72	2.82
New York, New Haven & Hartford	33	75	70	155	229	113	163	372	343	767	1 130	555	1.05	2.43	2.22	4.96	7.30	3.59
Rutland	47	9	28	29	31	29	182	32	105	111	121	110	1.52	0.29	0.91	0.96	1.02	0.94
	1	4	30	82	15	26	2	13	101	284	58	92	0.02	0.13	0.96	2.63	0.47	0.84
Total	62	49	45	52	46	51	221	177	158	184	167	181	2.07	1.64	1.49	1.72	1.52	1.69
GREAT LAKES REGION:																		
Ann Arbor	126	104	61	62	47	80	480	401	229	222	181	303	4.13	3.41	2.00	2.03	1.56	2.63
Delaware & Hudson	110	58	49	61	58	67	394	218	152	165	174	221	3.45	1.77	1.53	2.01	1.90	2.13
Delaware, Lackawanna & Western	61	60	94	90	79	77	254	251	388	360	349	320	1.98	1.94	3.03	2.89	2.49	2.47
Detroit & Toledo Shore Line	95	51	49	35	72	60	426	230	224	150	344	275	3.14	1.69	1.62	1.15	2.50	2.02
Erie	98	74	58	62	56	70	378	268	225	242	214	265	3.31	2.50	1.99	2.12	1.90	2.36
Grand Trunk Western	64	58	52	45	47	53	243	212	198	163	118	187	2.00	1.84	1.66	1.43	1.50	1.69
Lehigh & Hudson River	69	60	62	69	70	66	312	256	261	290	344	293	2.56	2.21	2.29	2.56	2.58	2.44
Lehigh & New England	89	80	39	76	75	72	370	338	164	337	327	307	2.94	2.66	1.29	2.53	2.48	2.38
Lehigh Valley	70	64	44	53	44	55	273	252	161	196	149	206	2.32	2.13	1.44	1.76	1.47	1.82
Monongahela	44	34	34	54	39	41	164	130	127	126	159	141	1.50	1.16	1.15	1.84	1.33	1.40
New York Central	96	54	78	56	62	69	363	200	257	180	211	242	3.12	1.75	2.52	1.80	1.99	2.24
New York, Chicago & St. Louis	108	91	91	79	60	86	411	352	334	305	240	328	3.48	2.91	2.94	2.53	1.94	2.76
New York, Susquehanna & Western	39	34	33	21	6	27	178	95	115	81	29	100	1.36	1.17	1.14	0.72	0.21	0.92
Pittsburgh & Lake Erie	92	47	47	44	107	67	361	179	146	147	254	217	2.99	1.53	1.54	1.45	3.52	2.21
Pittsburgh & West Virginia	91	40	22	32	32	43	408	183	102	133	135	192	2.96	1.31	0.73	1.04	1.04	1.42
Wabash	85	68	64	38	38	59	334	270	262	165	174	241	2.71	2.18	2.03	1.21	1.20	1.87
Total	91	62	70	58	58	68	348	234	249	204	209	249	2.96	2.01	2.28	1.87	1.90	2.20
CENTRAL EASTERN REGION:																		
Akron, Canton & Youngstown	101	136	120	63	85	101	357	507	413	249	375	380	3.43	4.60	4.06	2.12	2.88	3.42
Baltimore & Ohio	36	44	78	69	66	59	111	131	261	232	226	192	1.27	1.53	2.74	2.44	2.30	2.06
Bessemer & Lake Erie	58	33	22	65	72	50	270	144	64	267	289	207	1.85	1.02	0.68	1.92	2.14	1.52
Central R.R. of N.J.	65	51	50	41	26	47	247	200	182	130	97	171	1.84	1.82	1.79	1.45	0.92	1.56
Chicago & Eastern Illinois	66	45	59	55	65	58	244	157	201	200	254	211	2.17	1.49	1.93	1.81	2.12	1.90
Chicago & Illinois Midland	47	110	57	39	19	58	180	393	239	130	145	217	1.58	3.70	1.92	1.28	1.29	1.96
Detroit, Toledo & Ironton	139	96	111	77	57	96	424	333	381	256	207	320	4.72	3.34	3.84	2.68	1.99	3.11
Elgin, Joliet & Eastern	29	18	24	21	40	26	99	54	68	71	150	88	0.95	0.60	0.73	0.69	1.30	0.85
Illinois Terminal	78	50	83	61	47	64	226	148	244	184	149	190	2.43	1.54	2.59	1.92	1.53	2.00
Litchfield & Madison a	-	-	-	67	52	-	-	-	-	235	182	-	-	-	-	2.15	1.62	-
Long Island	84	78	72	69	63	73	338	291	270	307	290	299	2.91	2.70	2.50	2.39	2.17	2.53
Missouri-Illinois	41	32	30	32	19	31	113	87	77	87	54	84	1.31	1.03	0.95	1.03	0.60	0.98
Monon	165	65	85	102	73	98	521	212	276	328	240	315	5.30	2.10	2.73	3.28	2.34	3.15
Pennsylvania	94	42	55	62	67	64	357	155	196	232	284	245	3.27	1.45	1.93	2.17	2.35	2.23
Penna.-Reading Seashore Lines	89	68	72	49	53	66	402	243	272	197	246	272	3.28	2.51	2.66	1.80	1.96	2.44
Reading Co.	77	44	45	54	52	54	290	167	169	205	209	208	2.76	1.58	1.61	1.96	1.86	1.95
Staten Island Rapid Transit	71	42	79	36	48	55	215	150	228	166	237	199	2.76	1.65	3.10	1.40	1.87	2.16
Western Maryland	76	49	43	72	69	62	302	211	182	305	301	260	2.53	1.70	1.50	2.48	2.39	2.12
Total	76	45	61	63	63	62	280	160	213	227	251	226	2.62	1.57	2.12	2.18	2.20	2.14
POCAHONTAS REGION:																		
Chesapeake & Ohio	79	55	56	40	47	55	276	185	197	148	175	196	2.62	1.80	1.86	1.31	1.54	1.83
Norfolk & Western	115	68	83	101	98	93	370	218	263	388	386	325	3.71	2.21	2.67	3.27	3.15	3.00
Richmond, Fred'burg & Potomac	97	136	72	31	52	78	361	519	284	125	210	300	3.24	4.54	2.34	1.02	1.70	2.57
Virginian	114	88	84	89	89	93	374	299	288	305	322	318	3.71	2.86	2.75	2.91	2.90	3.03
Total	93	64	67	62	66	70	315	213	227	233	252	248	3.06	2.08	2.19	2.04	2.15	2.30
SOUTHERN REGION:																		
Alabama Great Southern	80	82	76	64	71	75	292	282	286	240	320	284	2.64	2.72	2.53	2.10	2.34	2.47
Atlanta & St. Andrews Bay	110	50	93	69	75	79	487	222	412	310	338	354	3.63	1.63	3.06	2.28	2.45	2.61
Atlanta & West Point	169	150	152	164	135	154	613	550	533	575	528	560	5.68	5.03	5.10	6.05	4.99	5.37
Atlantic Coast Line	153	87	103	97	85	105	517	299	342	339	310	361	4.94	2.80	3.30	3.12	2.72	3.38
Carolina & Northwestern a	-	-	-	136	84	-	-	-	-	593	339	-	-	-	-	4.98	2.91	-
Central of Georgia	100	109	103	127	107	109	306	340	312	394	349	340	3.45	3.77	3.55	4.40	3.70	3.77
Charleston & Western Carolina	191	213	176	225	217	204	762	821	692	979	930	837	6.55	7.27	6.00	7.64	7.37	6.97
Cincinnati, New Orleans & Tex.Pac.	97	90	70	70	76	81	363	340	266	281	355	321	3.29	3.04	2.38	2.37	2.89	2.73
Clinchfield	457	246	128	152	123	221	1487	753	395	595	457	737	14.29	7.66	4.00	4.71	3.84	6.91
Florida East Coast	134	138	126	152	171	144	490	507	455	576	677	541	4.63	4.76	4.33	5.24	5.90	4.97
Georgia R.R.	182	159	147	165	151	157	541	538	491	553	537	532	5.34	5.22	4.84	5.43	4.98	5.16
Georgia & Florida	250	241	227	203	104	209	623	593	500	494	222	486	9.27	8.93	8.39	8.25	3.86	7.74
Georgia Southern & Florida	169	324	273	127	70	193	588	743	621	456	279	537	5.37	10.29	8.69	4.03	2.21	6.12
Gulf, Mobile & Ohio	131	88	86	89	83	95	406	286	276	284	280	306	4.15	2.79	2.70	2.81	2.63	3.02
Illinois Central	102	84	65	83	75	82	319	283	223	294	292	282	3.31	2.76	2.14	2.73	2.45	2.68
Louisville & Nashville (Incl.N.C.&St.L.)	132	103	73	92	78	96	408	323	228	289	256	301	4.63	3.63	2.58	3.24	2.75	3.67
Mississippi Central	67	66	62	68	76	68	262	260	270	269	368	286	2.26	2.22	2.09	2.30	2.57	2.29
New Orleans & Northeastern	249	216	208	197	170	208	592	501	491	467	465	503	8.53	7.39	7.10	6.71	5.85	7.12
Norfolk Southern	-	-	-	100	105	-	-	-	-	460	491	-	-	-	-	3.22	3.42	-
Piedmont & Northern a	-	-	-	171	161	-	-	-	-	532	530	-	-	-	-	5.58	5.21	-
Savannah & Atlanta a	72	89	89	73	58	76	249	320	312	263	224	274	2.38	2.96	2.96	2.43	1.93	2.53
Seaboard Air Line	82	75	74	67	54	70	293	264	252	267	254	266	2.65	2.41	2.38	2.15	1.74	2.27
Southern Ry.	110	146	128	117	90	118	338	394	334	328	243	327	3.62	4.81	4.23	3.85	2.99	3.90
Tennessee Central	168	168	174	205	180	179	609	612	607	718	702	650	5.63	5.60	5.82	6.84	6.01	5.98
Western Ry. of Alabama																		
Total	118	99	89	93	81	96	386	325	290	323	302	325	3.91	3.27	2.95	3.09	2.67	3.18

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Table E

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class 1 roads in the United States and large Canadian roads, by years, and for the average of the five years 1953 to 1957, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1953	1954	1955	1956	1957	5 year average	1953	1954	1955	1956	1957	5 year average	1953	1954	1955	1956	1957	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western(Inc.C.St.P.M.&O)	77	36	47	68	87	63	$267	$122	$174	$257	$316	$227	2.60	1.20	1.59	2.27	2.94	2.12
Chicago Great Western	75	54	92	95	112	86	297	214	305	340	393	304	2.51	1.82	3.08	3.18	3.73	2.86
Chicago,Milwaukee,St.Paul & Pacific	64	54	66	60	44	58	175	145	213	213	164	182	2.06	1.76	2.15	1.95	1.44	1.87
Duluth,Missabe & Iron Range	67	61	51	39	55	55	218	223	196	148	223	202	2.23	2.05	1.71	1.30	1.83	1.82
Duluth,South Shore & Atlantic	185	138	139	134	105	140	593	456	435	426	348	452	6.39	4.77	4.80	4.53	3.53	4.80
Duluth,Winnipeg & Pacific	75	57	45	45	43	53	211	183	146	156	151	169	2.62	1.99	1.57	1.59	1.51	1.86
Great Northern	89	74	68	68	57	71	331	285	268	285	251	284	2.84	2.36	2.18	2.17	1.82	2.27
Green Bay & Western	192	253	130	135	60	154	679	883	401	460	220	529	6.67	8.78	4.53	4.70	2.09	5.35
Lake Superior & Ishpeming	77	54	65	79	76	70	209	155	193	253	222	206	2.51	1.79	2.17	2.65	2.52	2.33
Minneapolis & St.Louis	165	137	131	100	92	125	488	417	368	290	294	371	5.47	4.59	4.39	3.33	3.06	4.17
Minneapolis,Northfield & Southern a	-	-	-	67	132	-	-	-	-	284	523	-	-	-	-	2.40	4.74	-
Minpls.,St.Paul & S.S.Marie (Inc.Wis.C.)	101	93	90	99	89	94	346	310	290	291	281	304	3.37	3.10	2.99	3.28	2.93	3.13
Northern Pacific	54	52	43	42	46	47	180	180	147	150	169	165	1.85	1.79	1.49	1.45	1.59	1.63
Spokane International	432	471	240	229	334	341	1443	1585	792	698	1235	1151	14.78	16.14	8.19	7.82	11.42	11.67
Spokane,Portland & Seattle	55	61	61	90	87	72	211	236	235	368	365	283	1.71	1.99	1.98	3.10	2.83	2.32
Total	79	62	64	68	66	68	263	208	221	244	246	236	2.61	2.05	2.13	2.24	2.20	2.25
CENTRAL WESTERN REGION:																		
Atchison,Topeka & Santa Fe	68	64	79	79	57	69	211	193	244	246	181	215	2.12	1.99	2.49	2.46	1.79	2.17
Chicago,Burlington & Quincy	58	41	35	40	41	43	195	136	116	134	139	144	1.86	1.34	1.14	1.30	1.33	1.40
Chicago,Rock Island & Pacific	81	73	68	65	61	70	218	193	178	181	186	191	2.73	2.46	2.28	2.17	2.05	2.34
Colorado & Southern	67	53	49	49	45	53	224	176	163	171	171	181	2.24	1.76	1.63	1.63	1.48	1.75
Colorado & Wyoming	29	146	25	27	74	60	109	682	99	107	308	261	0.93	4.74	0.80	0.88	2.38	1.95
Denver & Rio Grande Western	79	54	48	65	51	59	327	229	194	247	246	249	2.54	1.75	1.55	2.08	1.66	1.92
Fort Worth & Denver	71	64	72	93	65	73	225	216	239	315	265	252	2.36	2.13	2.40	3.06	2.15	2.42
Northwestern Pacific	245	208	251	147	139	198	802	714	811	576	490	679	8.49	7.23	8.72	5.11	4.88	6.89
Sacramento Northern	57	61	63	79	48	62	196	212	199	309	206	224	1.88	2.04	2.13	2.69	1.64	2.08
Southern Pacific Co. - Pac.Lines	74	79	74	61	62	70	248	253	253	238	242	247	2.50	2.61	2.43	2.02	2.05	2.32
Toledo,Peoria & Western	88	98	52	60	21	64	306	324	185	237	85	227	2.76	3.08	1.63	1.90	0.68	2.01
Union Pacific	73	50	72	65	60	64	252	171	250	239	229	228	2.57	1.76	2.56	2.31	2.11	2.26
Western Pacific	142	148	147	115	108	132	567	603	599	549	555	575	4.78	4.97	4.94	3.84	3.63	4.43
Total	73	64	69	66	58	66	239	204	225	226	208	220	2.41	2.10	2.28	2.17	1.89	2.17
SOUTHWESTERN REGION:																		
Kansas City Southern	182	46	95	68	54	89	582	136	280	212	166	275	5.76	1.44	3.01	2.14	1.71	2.81
Kansas,Oklahoma & Gulf	134	106	113	140	149	128	400	315	334	367	398	363	4.50	3.55	3.80	4.66	4.97	4.30
Louisiana & Arkansas	137	94	81	63	59	87	422	295	234	187	185	265	4.22	2.89	2.49	1.95	1.81	2.67
Missouri-Kansas-Texas Lines	128	99	94	105	191	123	357	290	264	292	579	356	4.04	3.11	2.98	3.32	6.00	3.89
Missouri Pacific Lines	132	114	114	100	75	107	394	324	335	294	228	315	4.28	3.69	3.71	3.25	2.42	3.47
St.Louis-San Francisco	81	84	87	90	73	83	232	243	243	256	223	239	2.55	2.68	2.73	2.86	2.35	2.63
St.Louis,San Francisco & Texas	98	74	112	68	59	82	278	219	333	192	200	240	3.14	2.39	3.58	2.17	1.89	2.63
St.Louis Southwestern Lines	149	74	100	81	97	100	437	221	301	258	307	305	4.78	2.38	3.21	2.63	3.13	3.23
Texas & New Orleans	106	106	102	87	57	92	276	268	279	233	162	244	3.84	3.84	3.70	3.12	2.05	3.31
Texas & Pacific	139	129	128	140	120	131	396	375	380	436	387	395	4.75	4.43	4.38	4.79	4.11	4.49
Texas Mexican	99	120	94	109	109	106	323	421	275	324	336	336	3.13	3.80	2.96	3.43	3.45	3.35
Total	121	101	104	97	88	102	352	287	297	279	268	297	3.98	3.35	3.39	3.16	2.88	3.35
Grand total, United States	89	70	73	72	67	74	300	230	242	247	243	252	2.96	2.31	2.43	2.38	2.22	2.46
CANADIAN ROADS:																		
Canadian National	139	118	112	117	116	120	406	354	345	356	347	361	4.76	4.06	3.84	3.98	3.94	4.12
Canadian Pacific	128	102	92	87	86	99	407	337	304	278	274	320	4.42	3.52	3.18	2.93	3.00	3.41
Ontario Northland	321	233	194	238	156	228	1073	966	862	1026	677	921	11.09	8.03	6.69	8.20	5.29	7.86

a Class II railroads prior to January 1, 1956. Data for prior years not available.

Note: Missouri Pacific Lines includes: Beaumont,Sour Lake & Western,New Orleans, Texas & Mexico, St.Louis,Brownsville & Mexico, San Antonio,Uvalde & Gulf, and International-Great Northern (1956 consolidation).

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C., from Annual Reports of Class I railways to the Interstate Commerce Commission.

May, 1958

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CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar Year ended December 31, 1957

Road	Cross ties laid in replacement: New wooden ties untreated (U) Number	Average cost	New wooden ties treated (T) Number	Average cost	Total all new wooden ties laid Number	Average cost	Ties other than wood ($) & second-hand (*) reapplied ties	Total ties applied	Miles of maintained tracks (item 25)	Estimated total cross ties in all maintained tracks (item 24)	Average number of cross ties per mile of maintained tracks	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of maintained track (thous.)	New wooden cross ties replacement averages: Per cent renewal to all ties in maintained tracks	Number laid per mile of maintained track	Renewal cost per mile of maintained track	Renewal cost per 1000 equated gross ton miles
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western(C.StP.M&O)	-	-	1 108 458	$3.62	1 108 458	$3.62	* 16 273	1 124 731	12 685.68	37 730 890	2 974	42 057 949	3 315	2.94	87	$316	9.54
Chicago Great Western	-	-	201 668	3.51	201 668	3.51	-	201 668	1 803.46	5 410 123	3 000	8 342 533	4 626	3.73	112	393	8.49
Chicago,Milwaukee,St.Paul & Pac.	67	$2.76	578 462	3.74	578 529	3.74	*186 094	764 623	13 205.95	40 291 404	3 051	53 563 651	4 056	1.44	44	164	4.04
Duluth,Missabe & Iron Range	-	-	57 190	4.09	57 190	4.09	-	57 190	1 047.91	3 121 740	2 979	6 815 685	6 504	1.83	55	223	3.43
Duluth,South Shore & Atlantic	-	-	58 913	3.33	58 913	3.33	-	58 913	562.62	1 666 579	2 962	1 438 595	2 557	3.53	105	348	13.63
Duluth,Winnipeg & Pacific	109	1.83	8 967	3.51	9 076	3.49	-	9 076	209.90	600 472	2 861	994 827	4 740	1.51	43	151	3.18
Great Northern	400	2.13	582 140	4.41	582 540	4.40	* 84 655	667 195	10 225.20	31 980 680	3 128	56 677 835	5 543	1.82	57	251	4.53
Green Bay & Western	-	-	16 601	3.64	16 601	3.64	-	16 601	275.35	793 008	2 880	668 913	2 429	2.09	60	220	9.05
Lake Superior & Ishpeming	6 093	1.52	15 166	3.49	21 259	2.93	-	21 259	280.93	842 790	3 000	196 472	699	2.52	76	222	31.68
Minneapolis & St.Louis	9 769	1.01	129 878	3.37	139 647	3.20	-	139 647	1 520.92	4 557 750	2 997	3 986 320	2 621	1.06	92	294	11.21
Minneapolis,Northfield & Southern	-	-	9 748	3.97	9 748	3.97	-	9 748	74.12	205 478	2 772	289 653	3 908	4.74	132	523	13.37
Kanpls.St.Paul & S.S.M.(Inc.WC)	45	1.20	423 878	3.17	423 923	3.17	-	423 923	4 776.64	14 453 744	3 025	18 911 910	3 958	2.93	89	281	7.11
Northern Pacific	270	1.05	422 612	3.68	422 882	3.68	-	422 882	9 194.87	26 671 695	2 901	41 241 255	4 485	1.59	46	169	3.77
Spokane International	-	-	59 814	3.69	59 814	3.69	-	59 814	178.87	523 726	2 928	420 613	2 352	11.42	334	1 235	52.52
Spokane,Portland & Seattle	-	-	99 763	4.19	99 763	4.19	-	99 763	1 142.80	3 520 445	3 081	6 612 175	5 786	2.83	87	365	6.32
Total	16 753	1.23	3 773 258	3.72	3 790 011	3.71	287 022	4 077 033	57 187.22	172 370 524	3 014	242 218 386	4 236	2.20	66	246	5.80
CENTRAL WESTERN REGION:																	
Atchison,Topeka & Santa Fe	-	-	1 122 586	3.17	1 122 586	3.17	-	1 122 586	19 649.96	62 742 321	3 193	161 342 901	8 211	1.79	57	181	2.21
Chicago,Burlington & Quincy	-	-	473 558	3.39	473 558	3.39	* 85 584	559 142	11 565.93	35 715 592	3 088	62 512 350	5 405	1.33	41	139	2.57
Chicago,Rock Island & Pacific	-	-	583 409	3.05	583 409	3.05	-	583 409	9 560.70	28 490 812	2 980	50 404 869	5 272	2.05	61	186	3.53
Colorado & Southern	-	-	34 984	3.85	34 984	3.85	* 2 052	37 036	784.83	2 360 310	3 007	3 978 021	5 069	1.48	45	171	3.38
Colorado & Wyoming	-	-	7 899	4.17	7 899	4.17	-	7 899	107.01	332 508	3 107	67 061	627	2.38	74	308	49.14
Denver & Rio Grande Western	-	-	158 598	4.80	158 598	4.80	* 29 156	187 754	3 090.84	9 562 300	3 094	19 159 347	6 199	1.66	51	246	3.97
Fort Worth & Denver	-	-	97 414	4.08	97 414	4.08	* 2 792	100 206	1 496.85	4 536 216	3 031	5 095 429	3 404	2.15	65	265	7.79
Northwestern Pacific	818	2.32	58 969	3.54	59 787	3.53	-	59 787	430.45	1 226 067	2 848	1 778 998	4 133	4.88	139	490	11.85
Sacramento Northern	-	-	13 911	4.26	13 911	4.26	-	13 911	287.36	848 517	2 953	104 072	362	1.64	48	206	57.00
Southern Pacific Co.-Pac.Lines	300	2.82	748 725	3.87	749 025	3.87	* 408	749 433	12 001.85	36 602 027	3 050	119 431 402	9 951	2.05	62	242	2.43
Toledo,Peoria & Western	-	-	6 088	3.97	6 088	3.97	-	6 088	284.16	900 219	3 168	1 048 484	3 690	0.68	21	85	2.30
Union Pacific R.R.	584	2.52	801 326	3.84	801 910	3.84	-	801 910	13 440.75	37 970 058	2 825	132 105 752	9 829	2.11	60	229	2.33
Western Pacific	73	3.64	168 300	5.14	168 373	5.14	* 707	169 080	1 558.10	4 643 245	2 980	12 339 783	7 920	3.63	108	555	7.01
Total	1 775	2.52	4 275 767	3.60	4 277 542	3.60	120 699	4 398 241	74 258.81	225 930 192	3 042	569 368 269	7 667	1.89	58	208	2.71
SOUTHEASTERN REGION:																	
Kansas City Southern	-	-	74 598	3.07	74 598	3.07	-	74 598	1 376.16	4 350 435	3 161	9 805 542	7 125	1.71	54	166	2.33
Kansas,Oklahoma & Gulf	-	-	52 939	2.67	52 939	2.67	-	52 939	354.85	1 065 216	3 002	1 075 297	3 030	4.97	149	398	13.14
Louisiana & Arkansas	-	-	52 485	3.13	52 485	3.13	-	52 485	890.54	2 901 224	3 258	4 839 505	5 434	1.81	59	185	3.40
Missouri-Kansas-Texas Lines	-	-	699 154	3.04	699 154	3.04	-	699 154	3 667.39	11 658 475	3 179	15 515 609	4 231	6.00	191	579	13.69
Missouri Pacific Lines	1 310	1.50	885 884	3.05	887 194	3.05	-	887 194	11 886.43	36 651 519	3 083	65 125 177	5 479	2.42	75	228	4.35
St.Louis-San Francisco	-	-	430 128	3.04	430 128	3.04	-	430 128	5 664.08	18 341 529	3 238	28 945 075	4 936	2.15	73	223	4.52
St.Louis,San Francisco & Texas	-	-	8 710	3.40	8 710	3.40	-	8 710	148.11	461 504	3 116	692 339	4 674	1.89	59	200	4.28
St.Louis Southwestern Lines	-	-	170 287	3.15	170 287	3.15	* 1 359	171 646	1 748.54	5 435 848	3 109	14 057 687	8 040	3.13	97	307	3.82
Texas & New Orleans	-	-	311 402	2.85	311 402	2.85	-	311 402	5 485.28	15 189 357	2 769	31 517 451	5 746	2.05	57	162	2.81
Texas & Pacific	-	-	267 193	3.22	267 193	3.22	-	267 193	2 224.37	6 504 113	2 924	19 020 703	8 551	4.11	120	387	4.52
Texas Lexican	134	.50	26 057	3.10	26 191	3.08	-	26 191	240.22	760 060	3 164	288 052	1 199	3.45	109	336	28.04
Total	1 444	1.41	2 978 837	3.04	2 980 281	3.04	1 359	2 981 640	33 885.97	103 319 280	3 049	190 882 437	5 633	2.88	88	268	4.75
Grand total - United States	193 626	2.02	21 331 607	3.64	21 525 233	3.62	536 992	22 082 225	321 673.47	970 720 544	3 018	2 115 246 938	6 576	2.22	67	243	3.69
CANADIAN ROADS:																	
Canadian National	65 255	1.80	3 275 706	3.02	3 340 961	2.99	-	3 340 961	28 705.00	84 803 257	2 954	b	b	3.94	116	347	b
Canadian Pacific	55 651	2.42	1 794 566	3.23	1 850 217	3.20	-	1 850 217	21 326.17	61 578 511	2 887	96 893 148	4 543	3.00	88	274	6.06
Ontario & Northland	-	-	104 246	4.33	104 246	4.33	-	104 246	666.13	1 972 087	2 961	2 732 490	4 102	5.29	156	677	16.51

a Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

b Not reported.

Note: "Average cost" as shown in Columns 3, 5 and 7, represents storekeepers average cost of ties charged out and used. They are not the actual costs or prices paid for the ties purchased during the period.

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from Annual Reports of Class I Railways to the Interstate Commerce Commission.

May 1958

Advance Report of Committee 17—Wood Preservation

P. D. BRENTLINGER, *Chairman*

Termite Control Investigation

A. DIGEST

This report describes a service test installation designed to secure data on the protection afforded against attack by termites to southern yellow pine, coast-type Douglas fir and red oak timbers by the nine commercial preservatives now generally used by the railroads. Each of the species of wood was given three different retentions of each preservative.

The installation consists essentially of 1296 treated 2- by 4- by 18-in stakes buried vertically to half their length in the termite-infested ground of the Austin Cary Memorial Forest of the University of Florida near Gainesville, Fla., as shown in Figs. 5 to 7, incl.

The specimens were treated under controlled laboratory conditions and the preservatives were chemically analyzed at the U. S. Forest Products Laboratory in Madison, Wis. The results of the chemical analysis compared with AREA specification requirements are shown in Table 1. The test specimens, including 30 untreated control stakes, are distributed over 10 plots located in the test area as shown in Fig. 8.

The investigation will continue over a 15-year period, with an annual inspection contemplated to determine the rate of termite attack.

B. FOREWORD

The termite problem exists because of man's attempt to change the ordinary processes of nature by preserving wood for his own use over considerable periods of time, while it is the immemorial function of the termite and associated organisms to break

wood down and return it to the soil and the atmosphere. Among the first experiments to determine which chemical wood preservatives were most effective in deterring termite attack were the tests at Falls Church, Va., under the supervision of the Forest Products Laboratory.[1] Then followed similar tests on southern yellow pine specimens on an inter- at Falls Church indicated that good protection of southern yellow pine specimens was national basis with locations in South Africa, Australia, Hawaii and Panama.[2] The tests obtained by use of coal tar–creosote impregnation under pressure. The international tests are still in progress, and some of the preservatives under test are showing promise.

In 1928 the Termite Investigation Committee was promoted by the University of California and sponsored by interested industries and some of the western railroads. The results of the investigation of that committee, while indicative of the value of certain preservatives, were not conclusive in that the time period of the tests covered only three years. The Forest Products Laboratory started similar test installations in 1938, principally at Saucier, Miss., on pine specimens only, and progress reports indicate good results with some of the preservatives being used in the test herein described.

The first tests sponsored by the AREA, started in 1939 at Florrisant, Mo., involved the exposure of 344 specimens, each 2 in by 4 in by 2 ft long, so installed that only 6 in of their length was above ground. Specimens of southern pine were used for 18 preservatives and of Douglas fir for one preservative. An inspection was made in 1944, and a progress report appears in the Proceedings, Vol. 47. Further inspections were anticipated, but circumstances made it necessary to discontinue the tests before they could be made. It is thus seen that while several tests have been started, there is but little conclusive information based on controlled exposure over a long-time period.

The present AREA-sponsored test was started with nine preservatives being used on each of three species of wood and with three retentions of each of the preservatives. Arrangements were made to locate the test area in the Austin Cary Memorial Forest near Gainesville, Fla., which is controlled by the University of Florida (see Fig. 8). This location is considered ideal in that it is in an area infested by termites and in a climate favorable to the rapid growth of the termites; also the fact that the area is under the supervision of the University makes it desirable because its continued availability is assured.

J. O. Blew of the Forest Products Laboratory and Dr. J. B. Huffman of the University of Florida extended invaluable help in the preliminary work incident to the organization of the project, and such assistance was greatly appreciated. The project is under the general direction of G. M. Magee, director of engineering research, and under the immediate supervision of E. J. Ruble, research engineer structures, assisted by L. R. Morgan, assistant research engineer structures—all of the AAR research staff.

C. TEST SPECIMENS

The pine and fir specimens were cut from 1⅝-in by 3⅝-in by 16-ft (actual size) lumber selected from the stock pile in dealers yards. It was necessary to purchase the oak directly from a sawmill in 2- by 4-in stock and then have it surfaced to 1⅝ by 3⅝ in. The specimens were cut at the AAR Research Center, first to 20-in lengths and then, after seasoning to an air dry condition or below, to the final 18-in lengths. The specimens were marked so as to identify the species, stick number and piece number. For example, in the designation F2C the letter F indicates fir species, the number 2

[1] "Our Enemy, the Termite" by Thomas Elliott Snyder, Comstock Publishing Co., Ithaca, N. Y., 1948.

[2] AWPA Proceedings, 1957, page 225.

indicates the second 16-ft length of stick that was cut, and C represents the third specimen from the end of the stick. After 700 specimens of each species were so marked and cut, they were bundled in groups of 30 and shipped to the U. S. Forest Products Laboratory at Madison for controlled treatment.

D. TREATMENT

As previously mentioned, tests have been made with various preservatives which, although not carried far enough to furnish conclusive evidence, did provide indications as to which preservatives promised the best results. Based on such indications a selection of nine of the most promising and generally used preservatives was made, as shown below:

1. Coal tar creosote, furnished at no charge by the Interlake Iron Corporation.
2. Chromated zinc chloride, furnished at no charge by E. I. DuPont de Nemours and Co.
3. Tanalith, furnished at no charge by Koppers Co., Inc.
4. Pentachlorophenol, furnished at no charge by the Chapman Chemical Company.
5. Copper naphthenate, purchased.
6. Acid copper chromate (Celcure), purchased.
7. Ammoniacal copper arsenite (Chemonite), furnished at no charge by J. H. Baxter and Company.
8. Chromated zinc arsenate (Boliden Salt), furnished at no charge by the Taylor–Colquitt Company.
9. Chromated copper arsenate (Greensalt), furnished at no charge by Koppers Co., Inc.

Samples of these preservatives were chemically analyzed at the Forest Products Laboratory, and the results of this analysis compared with the AREA specification requirements are shown in Table 1. It can be seen that in general there is close conformity between the actual analysis and the requirements of the AREA specifications, and the following explanations are given to account for the differences that did occur:

Preservative No. 5—Copper Naphthenate

AREA specifications require not less than 0.1 lb per cu ft of metallic copper in the copper naphthenate treating solution; however, the 1.2 percent copper as shown in the analysis when used in an 8 lb per cu ft retention very nearly results in the amount stated in the specifications. The 4 lb per cu ft retention will, of course, be much less than specification requirements, but may be valuable on a trial basis.

Preservative No. 6—Acid Copper Chromate (Celcure)

The AREA specification for this preservative requires a chromic acid content of 1.70 percent, but AWPA Standard A–2–56 provides only for analysis of total chromate; hence, there was no determination of chromic acid, the content of which is adjusted to obtain a proper pH in the treating solution.

Preservative No. 7—Ammoniacal Copper Arsenite (Chemonite)

The AREA specification for this preservative requires an acetic acid content of 1.6 percent, but AWPA Standard A–2–56 does not provide for analysis for acetic acid; therefore, none was made.

Preservative No. 8—Chromated Zinc Arsenate (Boliden Salt)

As indicated on the analysis sheet there was a deficiency of arsenic acid as such, but there was enough additional arsenic in the sodium arsenate to result in a total arsenic content well above the minimum required by the specification; the sodium dichromate provides sufficient acidity to meet the requirements covering the pH of the solution which are designed to prevent the precipitation of insoluable compounds in the treating solution.

The preservative treatments of the specimens were completed under controlled laboratory conditions at the Forest Products Laboratory in August 1957 (see Fig. 1). The treatments were made in accordance with AREA Specifications for Treatment to the desired retention shown in Table 2. The desired retentions were adopted in conformity with AWPA standards for field tests in that the amounts shown under retention 2 are either at or near the so-called "threshold" concentration as indicated by previous investigations, while retentions 1 and 3 are half and double that concentration, respectively.

Table 3 show a typical record of treatment as made by the Forest Products Laboratory, and a similar record was kept for each run throughout the treatment of the entire lot of stakes. Preliminary runs were made with representative types of preservatives with each of the three species in order to adjust treating conditions and water-borne preservative solution concentrations to approach the desired retention. There was considerable variation in the retentions of the preliminary and regular treatments, however, particularly with the red oak and Douglas fir.

As previously stated the specimens were temporarily marked after cutting at the AAR Research Center to show species, stick number and piece. For permanent marking, metal tags were made at the Forest Products Laboratory, two being required for each treated specimen. One was marked to show the species, stick number and piece, similar to the method used in the temporary marking. This tag was mailed on the 3⅝-in face of the specimen near the top. The second tag was required to show the preservative number and retention number, e.g., in the designation "21" the number 2 indicates the preservative and the number 1 indicates the desired retention.

The U. S. Forest Products Laboratory realized it would be impossible to secure the exact desired retention for each test specimen. Hence, a sufficient number of untreated specimens were provided so that from 25 to 30 specimens were treated in each charge according to the total number of stakes for distribution over the various treatments. Then 10 specimens were selected for field installation having the least variance from the desired retention, care also being taken to exclude any specimens with heartwood or knots. After the 10 specimens were selected, an additional 6 specimens of each species, preservative and desired retention were selected for installation, which will be used for periodic extraction tests to determine the weathering rate of the preservative as compared with the termite attack.

Preservative retentions varied widely in the stakes treated in individual charges, particularly in the case of Douglas fir and oak. A few of the extra Douglas fir stakes with low and medium retentions of water-borne preservatives were cut up and found to be incompletely penetrated.

The retention in the oak specimens for the 15-year exposure tests varied from 4.3 to 5.0 lb per cu ft, with an average retention of 4.6 lb per cu ft compared with a desired retention of 4.0 lb per cu ft.

After the specimens were treated and selected, they were bundled together in groups of about 48, as shown in Fig. 2, and shipped to the University of Florida.

E. INSTALLATION

The site selected by the School of Forestry of the University of Florida for this investigation is about 1½ acres in area, located about 13 miles from Gainesville, as shown in Fig. 8. The site is a typical longleaf pine flatwoods area with pine, gallberry, dwarf palmetto, wire grass and various scrub oaks constituting the major vegetation. The particular area of the test plot is rather open, having very little overhead cover (see pictures, Figs. 6 and 7). The soil is a Leon fine sand with a hardpan layer approximately 3 ft below the surface. The plot is well drained, and although the soil has a tendency to become quite dry during droughty periods, ample moisture is available for both termites and decay. Since the test plot uses only about one-third of the area provided by the University, ample room is available for an extension of these tests or additional investigations in the future.

The installation of the specimens was started on November 4, 1957, by members of the AAR research staff, assisted by F. J. Fudge, timber engineer, New York Central System, and chairman of the Subcommittee on Destruction by Termites of AREA Committee 17, and Dr. J. B. Huffman of the School of Forestry. Extreme care was taken to obtain a uniform distribution of each species and retention throughout all of the 10 plots to insure impartial and uniform exposure. In order to achieve this distribution, the 10 stakes for each species, preservative and retention were placed in 10 separate piles as shown in the picture, Fig. 3. The 6 stakes of each type for the periodic extractions and the 30 untreated control specimens were then distributed among the 10 piles, thus making 10 piles of approximately 132 specimens in each pile.

The 10 plots were located and outlined by corner stakes as shown in Fig. 8. The individual rows at 3 ft centers in the north and south direction were marked with string, while the east and west rows at 4 ft centers were marked with stakes at the borders. The holes for the test specimens were made by first forcing the special spade shown in the picture, Fig. 4, into the ground and working it back and forth. The holes so formed were about 2 in by 4 in by 9 in deep. The test specimens were then placed halfway in the holes, with all identification tags on the north sides, and the soil tamped around them by foot (see Fig. 5).

A detailed record of the preservative treatment, retention and location of each test specimen has been prepared and is on file at the AAR Research Center for reference when inspections are made.

TABLE 1—CHEMICAL ANALYSIS OF PRESERVATIVES

No. 1 Coal Tar Creosote

Characteristic	*AREA Specification*	*Laboratory Analysis*
Water content	Not more than 3.0 percent	0.1 percent
Benzol insoluble	Not more than 0.5 percent	0.14 percent
Specific gravity at 38 deg C	Not less than 1.03 percent	1.087 percent
Distillate limits		
Up to 210 deg C	Not more than 5 percent	2.2 percent
235 deg C	Range between 5 to 25 percent	10.2 percent
270 deg C	Not less than 20 percent	31.3 percent
355 deg C	Range between 60 to 85 percent	72.6 percent
Spec. gr. of fractions at 38 deg		
from 235 deg to 315 deg C	Not less than 1.025 percent	1.0432 percent
315 deg to 355 deg C	Not less than 1.085 percent	1.1211 percent
Coke residue	Not more than 2 percent	1.54 percent

TABLE 1—(Cont'd)

No. 2 Chromated Zinc Chloride

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
Zinc Chloride—$ZnCl_2$	Not less than 77.5 percent	80.88 percent
Sodium Dichromate ($Na_2Cr_2O_7 2H_2O$)	Not less than 17.5 percent	19.12 percent

No. 3 Tanalith

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
Sodium Fluoride—NaF	Not less than 22 percent	23.55 percent
Pentavalent Arsenic ($Na_2HA_5O_4$)	Not less than 22 percent	25.65 percent
Hexavalent Chromium (Na_2CrO_4)	Not less than 34 percent	38.90 percent
Dinitrophenol (NO_2)$_2$.C_6H_3.OH	Not less than 10 percent	11.90 percent

No. 4 Pentachlorophenol

Treating Solution Charactertistic	*AREA Specification*	*Laboratory Analysis*
Pentachlorophenol Solution	4.5 to 5.5 percent	4.95 percent

Penta Preservative 202 E is a blend of 5 percent by weight of technical pentachlorophenol in 102 E oil. This oil has the following typical characteristics:

API Gravity at 60° F	29
Viscosity at 100° F. (SUS)	40
Pour Point °F	0
Flash Point, PMCC °F	190
I.B.P.	432
10%	465
50%	516
90%	615
F.B.P.	708
% Penta Solvency at 75° F.	13

Key
API—American Petroleum Institute
SUS—Saybolt Universal Seconds
PMCC.—Pensky–Martens Closed Cup Test
I.B.P.—Initial Boiling Point
F.B.P.—Final Boiling Point

No. 5 Copper Naphthenate

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
	Not less than 0.10 lb per cu ft *Manufacturers Specification*	0.096 lb per cu ft *Typical Analysis*
Solvent—Aromatic H-B oil as follows:		
API Gravity 60° F	24 (max)	20.5
Viscosity 100° F (SUS)	--------	45
Pour Point °F	--------	Minus 10
Distillation Range °F		
I.B.P.	400	490
10%	--------	512
50%	--------	540
90%	--------	584
F.B.P.	700	614
Flash Point, PMCC °F	190 (min)	230

No. 6 Acid Copper Chromate (Celcure)

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
Copper Sulphate ($CuSO_4.5H_2O$)	Not less than 45 percent	47.3 percent
Sodium Dichromate ($Na_2Cr_2O_7.2H_2O$)	Not less than 45 percent	52.7 percent
Chromic Acid (CrO_3)	1.70 percent	None shown as such

No. 7 Ammoniacal Copper Arsenite (Chemonite)

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*	
		Solution 1	Solution 2
Copper Hydroxide ($Cu(OH)_2$)	Not less than 55.7 percent	63.6 percent	63.0 percent
Arsenic Trioxide (As_2O_3)	Not less than 38.7 percent	36.4 percent	37.0 percent
Acetic Acid (CH_3CO OH)	1.6 percent	None shown as such	

TABLE 1 (Cont'd)

No. 8 Chromated Zinc Arsenate (Boliden Salt)

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
Arsenic Acid (H_3AsO_4)	Not less than 19 percent	17.6 percent
Sodium Arsenate (Na_2HAsO_4)	Not less than 18 percent	22.9 percent
Sodium Dichromate ($Na_2Cr_2O_7.2H_2O$)	14 percent	16.1 percent
Zinc Sulphate ($ZnSO_4 7H_2O$)	Not less than 41 percent	43.4 percent
Subject to following tolerance: Total arsenic in both arsenic acid and sodium arsenate.	Range 26.4 to 31.1 percent	Based on atomic weights, total arsenic calculated as 28.45 percent.

No. 9 Chromated Copper Arsenate (Green Salt)

Treating Solution Characteristic	*AREA Specification*	*Laboratory Analysis*
Potassium Dichromate $K_2Cr_2O_7$	Not less than 50 percent	55.3 percent
Copper Sulphate $CuSO_4 5H_2O$	Not less than 30 percent	32.3 percent
Arsenic Pentoxide $As_2O_5 2H_2O$	Not less than 10 percent	12.4 percent

TABLE 2—DESIRED RETENTION OF PRESERVATIVES

Preservative	*Retention, Lb per Cu Ft*		
	No. 1	*No. 2*	*No. 3*
No. 1. Coal-Tar Creosote	4.0	8.0	16.0
No. 2. Chromated Zinc Chloride	0.5	1.0	2.0
No. 3. Tanalith	0.25	0.50	1.0
No. 4. Pentachlorophenol	4.00	8.00	16.00
No. 5. Copper Naphthenate	4.00	8.00	16.00
No. 6. Acid Copper Chromate (Celcure)	0.50	1.00	2.00
No. 7. Ammoniacal Copper Arsenite (Chemonite)	0.25	0.50	1.00
No. 8. Chromated Zinc Arsenate (Boliden Salt)	0.50	1.00	2.00
No. 9. Chromated Copper Arsenate (Greensalt)	0.375	0.75	1.50

TABLE 3—TYPICAL RECORD OF TREATMENT

Date: August 16, 1957
Preservative: Coal Tar-Creosote
Retention: 4 lb (desired)
Size of Specimen: 1⅝ x 3⅝ x 18 in
Volume of Specimen: 0.05808 cu ft
90 lb air on at 7:56 am

Fill Cylinder at 8:11 am
175 lb pressure on at 8:15 am
175 lb pressure off at 10:15 am
26 in. final vacuum on at 10:18 am
26 in. final vacuum off at 10:48 am
Temperature: 195 to 200 deg F

Species	*Specimen Number*	*Untreated Weight Lb*	*Treated Weight Lb*	*Retention*		*Specimens Selected*
				Lb	*Lb/Cu Ft*	
Oak	O1E/11	2.40	2.78	0.38	6.5	
	O2C	2.80	3.07	0.27	4.6	x
	O4G	2.70	2.97	0.27	4.6	x

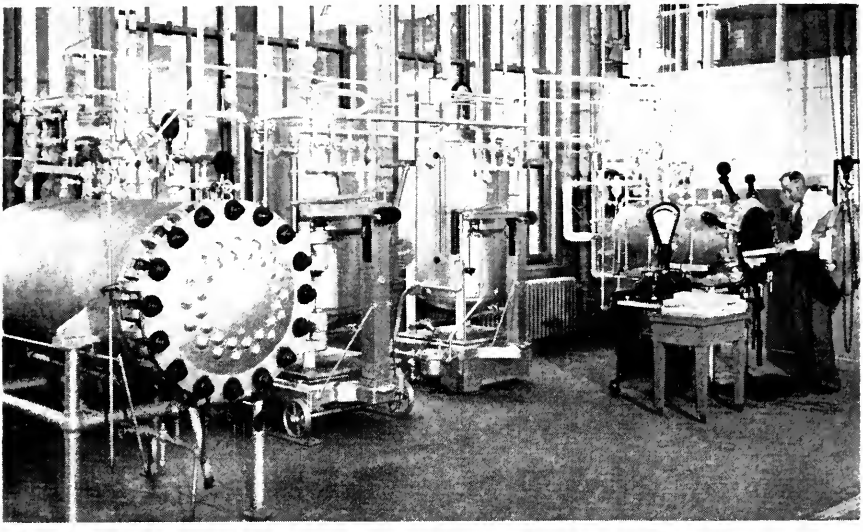


Fig. 1—Treating specimens at Forest Products laboratory.

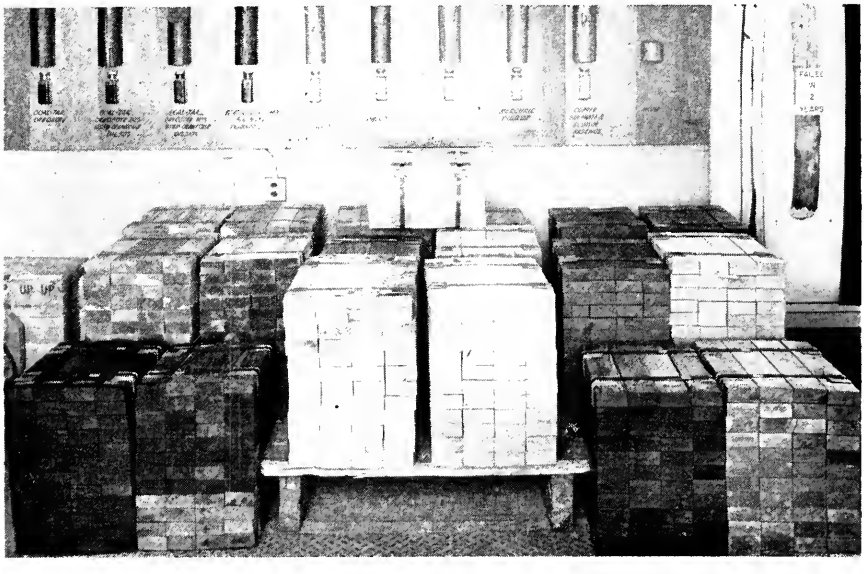


Fig. 2—View of treated specimens.

Fig. 3 (right)—Sorting specimens for random distribution in plots.

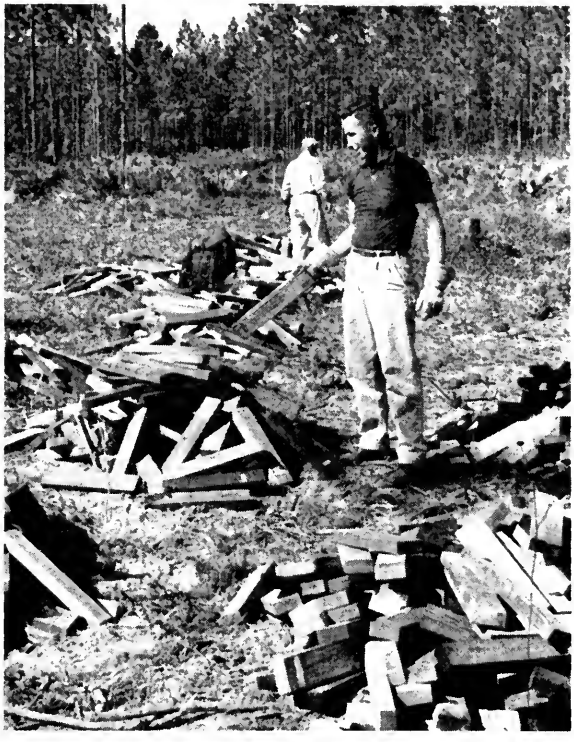


Fig. 4 (below)—Special spade used for installing specimens.

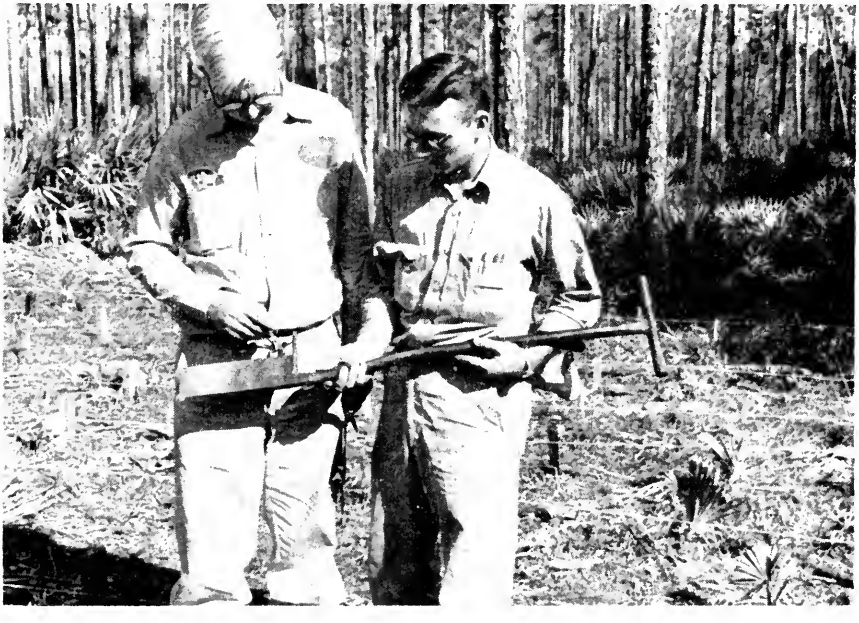


Fig. 5 (above)—Installed specimens showing identification tags.

Fig. 6 (left) — Recording the location of each specimen.

Fig. 7 (both photographs)—checking distribution of specimens.

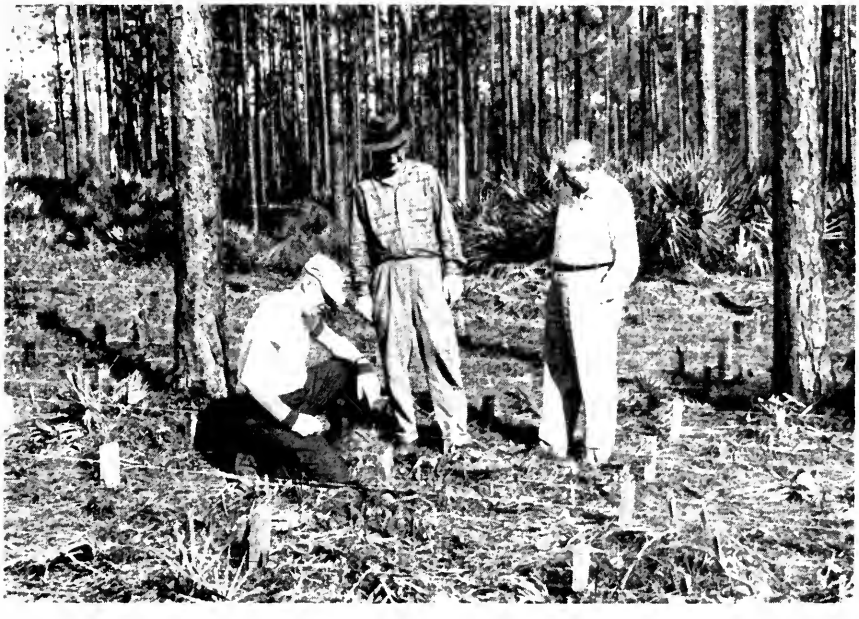
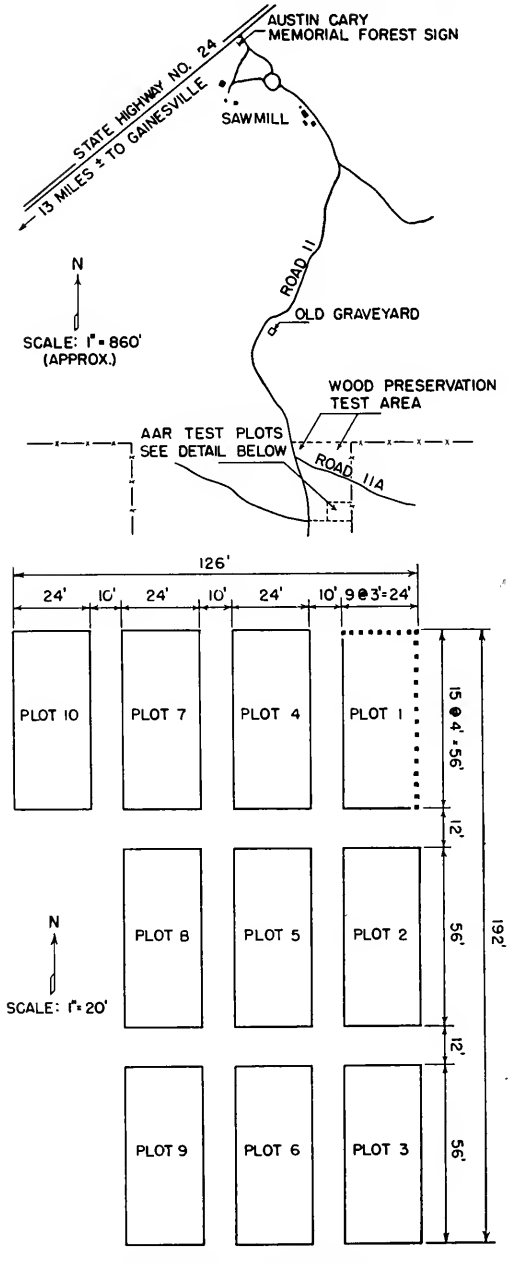


FIG. 8

LOCATION AND DETAIL OF TEST AREA



DETAIL OF PLOT LOCATION

▪ TEST SPECIMENS PLACED AS SHOWN

Advance Report of Committee 30—Impact and Bridge Stresses

D. S. BECHLY, *Chairman*

Tests of Timber Trestles on the Seaboard Air Line Railroad

A. DIGEST

This report contains a description and analysis of data obtained during the test of two ballasted-deck timber trestles on the Seaboard Air Line Railroad. One of these trestles is located near Boca Raton, Fla., and the other is near Fort Lauderdale, Fla. These locations were selected because of the relatively high moisture content of wood that exists there.

The tests were made under regularly scheduled trains at a complete range of speeds up to the maximum permitted. The regular way freight was used for the braking and traction runs. Only diesel locomotives were recorded.

Stresses were obtained in the stringers, piles and bracing. The lateral bent movements were measured as well as stringer deflections. Traction and braking forces were determined by measuring bending of the piles, pressure of the bulkhead against the embankment and axial stress in the running rails.

From an analysis of the data obtained on these two bridges, the following features are significant:

1. The live load was not distributed uniformly to the stringers. The stringers near the center of the bridge carried most of the load, and those under the ballast retainer carried practically none. (See Figs. 4 and 5).

2. The extreme recorded static tensile stress at the center of a span was 782 psi. This is 122 percent of the calculated stress for an assumed simple span. (See Table 1).

3. The extreme recorded static tensile stress in continuous stringers over a bent was 540 psi. (See Table 1).

4. Some added continuity was obtained in those stringers which extended beyond the cap.

5. An apparent vertical movement of a bent under load relative to adjacent bents caused a reduction of negative bending moment stress over this bent.

6. Higher stringer stresses were recorded in the end span than in the intermediate spans. The maximum recorded total tensile stress was 962 psi. (See Fig. 17).

7. The maximum recorded total stringer tensile stress over a bent was 554 psi. (See Fig. 9).

8. Stringer stress generally increased with speed, and most recorded maximum stresses were less than calculated. (See Figs. 6 to 17, incl.).

9. High impacts were recorded in the stringers of one of the bridges where vertical movement of a bent relative to adjacent bents occurred.

10. Stringer impacts generally increased with speed. (See Figs. 18 and 19).

11. The live load was not distributed uniformly to the piles; the four center piles carried most of the load. (See Figs. 20 and 21).

12. The maximum recorded total direct load in a pile was 12.8 tons.

13. Higher stresses were recorded in the sway braces when the bolts were tight than when they were loose, and there was an increase in stress with an increase in speed.

14. The maximum recorded stress in the sway bracing was + 73 psi. This is equivalent to a load of 2480 lb in the brace.

15. In order to determine stringer deflections, the simultaneous bent settlement must also be known. The maximum recorded net deflection of a stringer was 0.08 in.

16. The bracing was not partically effective in reducing lateral bent movement of these low bents since there was very little difference in movement between tight and loose bracing bolts.

17. The height of the bent may be a principal factor in determining the lateral bent movement. The maximum recorded movement for these low bents was 0.12 in.

18. The highest stringer stresses resulted from a relatively small percentage of the number of trains crossing the bridges.

19. Braking of the train across the bridges, but not stopping on them, produced negligible bending stresses in the piles. (See Figs. 30 and 31).

20. Braking to a stop on the bridges produced small bending in the piles.

21. Most of the total longitudinal force from braking to a stop on the bridges went into the rails. A total force in the rails of about 88 kips and 114 kips was recorded in the short bridge and long bridge, respectively. This is approximately 49 percent and 19 percent, respectively, of the estimated live load on the bridges.

22. Braking to a stop on the bridges also created a pressure on the bulkheads against the embankment. This was about 13 kips in the short bridge and 10 kips in the long bridge.

23. Tractive forces produced stresses about one-third of the stresses from braking.

24. A diesel locomotive unit produced a maximum duration at 100 percent of the static stress of 0.19 sec, and an average car produced a maximum duration at this stress of 0.13 sec. The 100 percent static stress level may not be the critical level.

25. The total cumulative loading time at full design stress could conceivably amount to about 71 days during the life of a timber stringer of, say, 50 years. This permits consideration of increased fiber stresses in bending as compared to those used for long-time loading. Further research is required to verify this.

B. FOREWORD

Committee 30—Impact and Bridge Stresses, has an assignment for the study of stresses of timber structures and in the past has reported on stresses in timber trestle approaches in conjunction with steel bridge tests. Early in 1954 it was recognized that a policy should be adopted having as its sole purpose the testing of timber structures. A field testing program was therefore developed covering trestles of ordinary construction and including a sufficient number of structures to establish ranges of stress, variations in span length and height, and distribution of loads to various types of timber trestles.

Since the strength of wood is partially dependent upon its moisture content, the geographical location of the trestle was carefully considered. It was also considered desirable to select locations where the climatic conditions were fairly uniform. The first trestles in the over-all testing program were accordingly located in southern Florida where the moisture content of the wood would be constant and relatively high.

The Seaboard Air Line Railroad suggested several possible locations, and two were selected: bridge 996.0 near Boca Raton and bridge 1009.0 near Fort Lauderdale. Both of these were accessible by the test truck, which was located near one end of the trestles during the test. All instruments required for the test were installed in this truck. Bridge 996.0 was tested in December 1944 and bridge 1009.0 in January 1955.

The general procedure in conducting these tests was the same for both trestles. The SR–4 strain gages and other recording devices were placed on the various elements of the trestle. Each gage was individually calibrated. The complete test of each trestle was divided into five series:

Series No. 1—Stringer Stresses.
Series No. 2—Pile Stresses.
Series No. 3—Stringer Deflection, Lateral Bent Movement, Bracing and Pile Stresses.
Series No. 4—Same as Series 3, but with Bracing Bolts Loosened.
Series No. 5—Stresses from Braking and Traction.

Runs were secured for about a week for Series No. 1, during which time regular trains were recorded at their normal operating speed. After a representative number of regular speed runs were obtained, special speed runs were requested to provide a complete range of speeds. Runs for Series Nos. 2, 3 and 4 were also secured under regular trains, but a complete range of speeds was not required for these series. The braking and traction runs of Series No. 5 were made with the regular way freight which operated in this vicinity. Loaded gravel cars immediately behind the engine were added to its regular consist to develop greater braking and traction forces.

These tests were conducted for AREA Committee 30, and were carried out under the general direction of G. M. Magee, director of engineering research, Engineering Division, AAR. The funds necessary for the tests and the analysis of the data were provided by the AAR.

The conduct of the tests, analysis of data and preparation of the report were under the immediate direction of E. J. Ruble, research engineer srtuctures, Engineering Division, AAR, assisted in the field by F. P. Drew, assistant research engineer structures, and M. F. Smucker, assistant electrical engineer, and in the office by D. W. Wilki, chief draftsman, and J. S. Nardi, assistant structural engineer. This report was prepared by Mr. Drew.

C. INSTRUMENTS

The instruments used in these tests to determine the strains in the various elements of the trestles consisted essentially of two 12-channel oscillographs which recorded the strains on photographic paper in response to the SR–4 electrical resistance strain gages. A detailed description of the oscillographs and their auxiliary units is given in AREA Proceeding, Vol. 46, 1945, page 201, and a description of the SR–4 strain gage with necessary equipment is in the Proceedings, Vol. 52, 1951, page 152.

The sensitivity of each SR–4 gage was determined that would produce a trace deflection of about an inch during the passage of the live load. Six-inch SR–4 gages were used on the wood surfaces, but the calibration and sensitivity were based on steel having a modulus of elasticity equal to 30,000,000 psi. A sensitivity of 1 in = 7500 psi was used for all gages on stringers. One inch trace deflection on the oscillogram equals a strain of 7,500/30,000,000 = 0.000250 in/in, and the stress in the stringer for 1 in trace deflection equals 0.000250 E_t, where E_t is the modulus of elasticity of the timber. The gages on the piles were calibrated for a sensitivity of 1 in = 2500 psi, and on the bracing for 1 in = 1250 psi, and the corresponding stress computed as indicated above.

The deflections of one of the stringers were measured by connecting the stringer to a small steel cantilever beam mounted on an independent support. Deflection of

the stringer also deflected this steel beam, and its flexural strain was recorded through the oscillograph. Three such deflection devices were used, one at the center of span and one at the adjacent bearings. These short steel beams had a tendency to vibrate at their own natural period, and such vibrations were transmitted to the oscillograph record. It was found that a coil through which passed a movable core produced a better record, and this was used on some of the runs at bridge 996 and on all runs at bridge 1009. The deflection beams were calibrated so that 1 in trace deflection was equivalent to 0.312 in stringer movement. The deflection coil was calibrated for 1 in trace deflection equivalent to 0.333 in stringer movement at bridge 996 and 0.167 in at bridge 1009.

The lateral movement of three of the bents of each trestle was measured with a coil similar to that used for deflection. The core wire was mounted on the end of a cap with the coil secured to a pole driven into the stream bed several feet from the outside pile to provide an independent support.

Pressure cells were used to measure the pressure of the bulkhead against the embankment during the braking runs. These cells, 3¾ in. in diameter and ⅝ in thick, have one face which is pressure sensitive. They were installed behind the bulkhead timbers, at a depth of 21 in, which was about in line with the mid-depth of the stringers. The active face of the cell was placed toward the embankment with the other face bearing against the bulkhead timber. About 1 in of soft clay was placed over the active face, and sand backfill was used to partially fill the trench. Crushed stone ballast completed the backfill. The response from these cells was recorded through the oscillograph, and a sensitivity of 1 in trace deflection was equivalent to 1.4 psi against the cell on bridge 996 and 2.8 psi on bridge 1009. The calibration of these cells was performed in an air tank under controlled air pressure.

D. TEST SPANS AND LOCATION OF GAGES

Bridge 996

This structure, rebuilt in 1950, is a four-span creosoted timber ballast-deck pile trestle located near Boca Raton on the railroad's main line between West Palm Beach and Miami. The trestle crosses Canal No. 48 where the maximum distance base of rail to ground line is 9 ft 6 in and to the water surface, 8 ft 4 in. As shown in Fig. 1, each span is about 11 ft 0 in long and the total length, face to face of bulkhead, is 45 ft 4 in. The bents consist of 6 driven piles each, and the intermediate bents are braced with two 4- by 8-in sway braces each. The caps are 14 in by 14 in by 14 ft 0 in. The deck is carried by ten 8- by 16-in southern pine stringers per span. These stringers are arranged to form a continuous lap-type deck with some of the stringers extending beyond the face of the cap, as indicated on Fig. 2. The deck planks are 3 in by 12 in by 13 ft 0 in with 8- by 8-in ballast retainers. The distance from base of rail to top of deck planks is about 9½ in. The center line of track was at the center line of trestle. This structure is shown in Photographs 1 and 2.

The capacity of the stringers in flexure is E 105.5 based on the simple span bending moment, 8 stringers per track, and an assumed stress of 1650 psi. This stress is for stringers graded to Southern Pine Inspection Bureau grading rules, paragraph 282 and 283, dense structural 65 (B&SP&T). Since these stringers were treated with a preservative, no reduction is made for decay hazard, and the wet stresses are used.

Strains were measured on the bottoms of the stringers at the center line of span and on the tops of the stringers over the center line of bent, as shown on Fig. 2. (To place strain gages on the tops of the stringers it was necessary to remove the ballast

Photograph 1—Seaboard Air Line timber trestle 996.0 near Boca Raton, Fla.

Photograph 2—Trestle 996 showing supports used for measuring lateral bent movement.

Photograph 3—Seaboard Air Line timber trestle 1009.0 near Fort Lauderdale, Fla.

between two cross ties and install shallow bulkheads to expose the stringers). Strains were also measured on the piles as close as practical to the ground line or the water surface, and on the sway braces near the cap end.

Strains were measured on the neutral axes of the running rails at both ends of the trestle.

In addition to the recording of strains from stringers, the deflection of one of the continuous stringers in span 3 was measured as well as the lateral movement of bents 2, 3 and 4, and the pressure of the south bulkhead against the embankment.

Bridge 1009

This structure, rebuilt in 1950, is a 13-span creosoted timber ballast-deck pile trestle located near Fort Lauderdale on the railroad's main line between West Palm Beach and Miami. The trestle crosses Cypress Creek, and the maximum distance from base of rail to ground line is 14 ft 6 in. This creek is affected by the ocean tide, and at high tide the distance from base of rail to water surface is 7 ft 8 in, and at low tide 10 ft 5 in. As shown in Fig. 1, each span is about 11 ft 0 in long and the total length, face to face of bulkheads, is 144 ft 4 in. The bents consist of 6 driven piles each, and the intermediate bents are braced with two 4- by 8-in sway braces each. Those bents near the center of the trestle where the height is greatest also have two 3- by 8-in sash braces. The caps are 14 in by 14 in by 14 ft 0 in. The deck is carried by ten 8- by 16-in southern pine stringers per span. These stringers form a continuous lap-type deck, with some of the stringers extending beyond the face of cap, as shown on Fig. 3. The deck planks are 3 in by 12 in by 13 ft 0 in, with 8- by 8-in ballast retainers. The distance from base of rail to top of deck planks is about 10½ in. The center of track over the test spans was at the center line of trestle.

The capacity of the stringers in flexure is E 105.5 based on the simple span bending moment, 8 stringers per track and an assumed stress of 1650 psi.

Strains were measured at points in this trestle as shown on Fig. 3, which are similar in location to those on bridge 996.

In addition to the recording of strains from strain gages, the deflection of one of the continuous stringers in span 12 was measured as well as the lateral movement of bents 11, 12 and 13 and the pressure of the south bulkhead against the embankment.

E. TEST TRAINS

Regular trains were used to secure all of the data comprising this report. Most of the runs were made at the regular operating speeds, but in some instances special movements were requested of certain trains. Only diesel locomotives are used in this territory, and those which were recorded during these tests are shown diagrammatically on Fig. 1. The axle loads and spacings shown were supplied by the railroad.

Diesel–Electric, Two-Axle, Class 1600

These locomotives are used principally for freight service. Their rating in terms of Cooper loading for moment at the center of an 11-ft 0-in simple span is E 49.4.

Diesel–Electric, Three-Axle, Class 3000

These locomotives are used principally for passenger service. Their rating in terms of Cooper loading for moment at the center of an 11-ft 0-in simple span is E 43.9.

F. ANALYSIS OF FIELD RECORDS

Test Records

The test records or oscillograms were recorded on 10 in wide sensitized paper. After each run, the run number and the oscillograph used were imprinted on the record. These run numbers refer to the log of runs taken during the test which shows the date and time the run was taken, the locomotive numbers, direction, speed, and other pertinent data. During the test of these two trestles a total of 552 oscillograms were obtained.

Stress Corrections

The sensitivity of each gage was established before each test series, and each channel was carefully calibrated. During the calibration each trace is offset with a fixed resistance, and the amount of this offset is recorded as the calibration offset. After each run this same resistance is shunted across the circuit to produce a trace offset. If this trace offset agrees with the calibration offset the sensitivity has remained as originally established. If the two offsets differ the sensitivity is corrected proportionally.

Moisture Content

When the program for testing timber trestles was established, it was recognized that the moisture content of the wood was an important property to determine, and that the more nearly constant this property could be maintained the more valid would be the test results when compared to future similar tests.

The moisture content of the wood was determined in the field at the time of test by means of a Delmhorst Moisture Meter. This device determines the moisture content through its effect upon the direct current electrical resistance of the wood. Metal probes are inserted into the wood, and the moisture content is read directly on a calibrated scale. Two sets of probes were used, the probes in one set had points which penetrated to a depth of ¼ in and measured the moisture content at the surface and throughout this ¼-in depth; the probes in the other set were 1 in long, and were insulated for the entire length except at the tip. The use of ¼-in tips then indicated surface moisture as well as absorbed moisture. The use of the 1-in tips, however, would indicate the moisture content at the 1-in depth and would not be influenced by temporary

fluctuations in surface moisture caused by rain, morning dew, etc. For the purposes of this report the moisture content at the 1-in depth was used.

The moisture content of each timber was measured as near to the strain gage as practical. The probes were inserted at right angles to the surface on which strains were being recorded and in such a way that the flow of current was with the grain. Separate sets of readings were taken for each test series, and when a series extended over a period of several days, readings were taken every two or three days. The moisture content varied considerably between each timber, but only slightly from day to day.

Average moisture contents were used for each test series. Thus, Series No. 1, bridge 996, involved only strain measurements in the stringers. Accordingly, 24 readings were taken on three different days during the reading of runs on this series. The average of these 72 readings was used as the moisture content of the stringers during the test period at bridge 996. Similarly, at bridge 1009 Series No. 1 involved only stringers, and 96 moisture readings were taken. The average moisture content of the stringers at bridge 996 was 32 percent and at bridge 1009, 27 percent.

Series No. 2 at both trestles involved only strains in piles. These piles were surrounded by water and the gage locations were close to the water surface. The wood was not only wet on the surface, but apparently wet throughout. In many cases the moisture meter readings were in excess of 65 percent. The wood, therefore, contained free water in the cell cavities as well as absorbed water in the wood fibers. The average of 48 readings was used at each bridge as the average moisture content of the piles. At bridge 996 this average was 42 percent and at bridge 1009, 56 percent.

Series Nos. 3, 4 and 5 involved fewer moisture content readings, but an average value was obtained as for the other two series, as follows:

Series	*Bridge*	*Avg. Moisture Content Percent*
3 & 4	996	48
	1009	35
5	996	47
	1009	46

The air temperature during these tests remained fairly constant, and the average throughout the testing period was 69 deg. The maximum temperature was 85 deg and the minimum, 55 deg. The effect of this temperature variation was not considered sufficient to change the strength properties of the wood for the purposes of this report.

When an electrical moisture meter is used to determine the moisture in creosote-treated wood, a correction factor is applied to readings below about 20 percent. However, in the case of these trestles the moisture content was higher than 20 percent, and thus no correction was made to the meter readings as taken.

Specific Gravity

Since the strength of wood is related to its specific gravity, it was necessary to determine this property for the various elements of the bridge which were tested. Accordingly, increment borings from the stringers, piles and bracing were obtained with an increment borer which actually cuts out a cylindrical specimen about $\frac{3}{16}$ in. in diameter by whatever length is desired up to the length of the tool. For this test a length of about 3 in was considered adequate. Usually two samples were obtained at each gage location. These samples were placed in glass bottles which were marked for identification. The small hole created by the removal of this increment boring was then filled with creosote oil to obviate possible future decay.

These specimens were then brought into the laboratory for processing. All of these specimens were taken from creosoted wood, and obviously the presence of the creosote oil somewhat complicated the determination of the density of the wood itself. The laboratory procedure was therefore divided into three steps:

Step 1—Determination of Volume of Creosoted Wood Samples

The specimens were removed from the bottles and three pieces selected about 1½ in long each. A pycnometer was then filled with mercury as shown in Photograph 4 and a wood specimen placed in it. The displaced mercury was weighed and the volume of the specimen obtained.

Step 2—Extraction of Creosote Oil

The creosote oil was removed from the specimens by dissolving it in toluene. The apparatus for doing this is shown in Photograph 5. The specimens are placed in small cloth thimbles suspended from condenser coils. This assembly is then placed in a flask which contains a small quantity of toluene. As the toluene boils, its vapors condense on the coils which are kept cool by a flow of water. The condensed toluene drips over the wood specimens washing out the creosote oil. As this cycle of vaporization and condensation continues, the creosote accumulates in the bottom of the flask. After about 3½ hr in the toluene bath, the same process is repeated using acetone. This removes the toluene from the wood. After 2 hr in the acetone bath, the specimens are put in an oven at 110 deg F for 12 hr. From the oven they are put in a dessicator and allowed to cool.

Photograph 4—Filling pycnometer with mercury for measuring volume of wood specimens.

Photograph 5—Apparatus for removing the creosote oil from wood specimens by dissolving in toluene.

Step 3—Determination of Density of Extracted Wood Samples

The specimens were removed from the dessicator one at a time and weighed. Their volume was then found by mercury displacement the same as in Step 1, and the density determined.

(The volume of the creosoted specimen obtained in Step 1 was taken only as a precautionary measure in case the specimen became so disseminated during the toluene-acetone cycle as to prevent an accurate volume determination after extraction).

The densities of the extracted specimens were calculated in metric units. Specific gravity, by definition, is the ratio of the weight to an equal volume of water. Since the weight of water in the metric system is 1 gm per cc, the specific gravity of these specimens is the same numerically as the density.

The specific gravity to be used for any one series was the average of the specific gravities for the separate gage locations in that series. The following values were used:

Series	*Bridge 996*	*Bridge 1009*	
No. 1	0.592	0.563	
No. 2	0.569	0.528	
No. 3	0.573	0.559	
No. 4	0.573	0.559	
No. 5	0.558	0.524	
	Avg. 0.573	Avg. 0.547	Avg. = 0.56

Modulus of Elasticity

Table 12 in Wood Handbook No. 72, published by the Forest Products Laboratory, gives strength properties of some of the commercial woods based on the test results of small, clear specimens. The values shown for modulus of elasticity are apparent moduli observed from deflections in flexure tests of the various wood species. This is not the true modulus of elasticity parallel to the grain because flexure of beams in the sizes commonly used for test includes shear deformations which add to the deflection and which are not considered in the conventional formula for calculating modulus of elasticity from deflection. However, for the purpose of this investigation the modulus of elasticity is used to convert measured strains into stress. The correct modulus to use for such conversion is the true modulus of elasticity as determined from strength tests in axial compression.

The Forest Products Laboratory has made a few tests to determine the modulus of elasticity in tension which indicate that the tension modulus may be 1 to 5 percent higher than the compression modulus in some species. It is concluded that since there are many values in compression and few in tension, the compression values are the best available approximation to the true modulus of elasticity.

The following values of the true modulus of elasticity of longleaf yellow pine in compression parallel to the grain were furnished by the Forest Products Laboratory:

Green		*12% Moisture*		*0% Moisture*
Spec. Grav.	E_L	*Spec. Grav.*	E_L	*Spec. Grav.*
0.536	1,935,000	0.582	2,229,000	0.62

Since the average specific gravity was determined to be 0.56, an adjustment to the above values is necessary. The moisture content at the time of test varied from 27 to 56 percent, which is above the moisture intersection point of 21 percent given in the table on page 86 of the Wood Handbook, so no adjustment for moisture content is necessary to the tabular values of the modulus of elasticity for green wood.

The specific gravity adjustment is described on pages 88 and 89 of the Wood Handbook. The compression modulus of elasticity within a species is thus directly proportional to the 1.25 power of the specific gravity. From the tabulation above, green longleaf yellow pine has a modulus of elasticity of 1,935,000 psi, corresponding to a specific gravity of 0.62 based on oven-dry weight and volume. The green modulus of elasticity corresponding to a specific gravity of 0.56 is, then,

$$E_L = \frac{1{,}935{,}000}{\left(\frac{0.62}{0.56}\right)^{1.25}} = 1{,}705{,}000 \text{ psi}$$

This value of modulus of elasticity was used for all series and both bridges to establish the modular ratio E_L/E_S, that was used to relate stress in the timber to that in steel on which the calibration of the oscillograph was based.

G. STATIC AND DYNAMIC EFFECTS

The oscillograph deflections, when multiplied by the proper stress factors, were tabulated and then analyzed for the purpose of determining the magnitude of the static stresses, total impacts, maximum live-load-plus-impact stresses and other dynamic effects of the moving loads, including the stresses developed from braking and traction.

1. Static Stresses in Stringers

The recorded static stress in the bottom fibers of the stringers at the center of the test spans, as shown in Table 1, are the maximum stresses produced by slow-speed runs (about 10 mph and slower) of each locomotive class. The calculated static stresses shown are based on the concentrated axle loads indicated on Fig. 1, with the locomotive positioned on the span as determined from the criteria for maximum stress. The outside stringers are assumed to carry no live load and the entire live load is distributed equally to eight 8- by 16-in stringers. No consideration was given to the continuity of the stringers, and simple span bending moments were used.

The recorded static stress in each stringer for each static speed run is shown. The maximum stress value is then compared with the calculated value in the form of a stress factor. The average stress factor appears in the column at the right. It can be seen that except for span 13, bridge 1009, all recorded values are less than the calculated.

The extreme static stress recorded on bridge 996 was 610 psi and the stress factor is 0.95. On bridge 1009 the values are 782 psi and 1.22, respectively.

These stress factors would be higher if the same position of locomotives was used for the calculated stress as occurred for the recorded stress. The theoretical position for maximum stress in the 11-ft simple span is with one wheel at center of span. Actually, because of the continuity, the maximum recorded stress did not occur with the wheel at the center of span. Thus, a closer correlation between calculated and recorded stresses could be obtained by using the position for maximum stress as indicated on the oscillogram, but this position is not normally used in the design calculation of stringer stresses.

While it is common practice to use continuous stringers, usually no advantage is taken of the effect of the continuity in reducing the positive bending moments. It can be seen from Table 1 that the recorded stresses in the end spans (spans 4 and 13) were higher than in the first intermediate spans (spans 3 and 12) and that the positive bending moments were reduced by the continuity. Only half of the stringers in the end spans are fully continuous, while all are continuous in the intermediate spans. Table 2 indicates the maximum recorded stresses over the bents, and it can be seen from the relation of the maximum negative to maximum positive bending moment stresses that at bridge 996 relatively high stresses were developed over the bents.

2. Simultaneous Maximum Recorded Stresses in Stringers

The maximum simultaneous stresses in the stringers at the center of spans or over the bents are shown on Figs. 4 and 5.

Each of these figures contains graphs showing the stress distribution to the stringers across the width of the deck. The top graph is for stresses at the center of the end span, the center graph is for stresses over the bent and the lower graph is for stresses at the center of the first intermediate span. The gage numbers refer to the location of gages on Figs. 2 and 3. Two lines are shown for static stresses and the other is for stresses at a higher speed. Stresses for the 1600 Class locomotive only are shown.

Bridge 996

It can be seen from the graphs of Fig. 4 that the stress distribution was such that the outside stringers had low stresses and hence carried very little of the total load and that the stringers toward the center of the bridge carried the highest stress. Except for the two simple span stringers 9 and 11, this distribution was somewhat parabolic

across the deck and remained nearly the same for the higher speed as for the static speed.

The center graph shows the distribution across the deck at center of bent 4. Here also the stringers toward the center of the bridge carried the highest stress. The stresses are indicated for the stub stringers 16 and 19, but are not included as points on the graph because they are not comparable to the fully continuous stringers 15, 17, 18 and 20.

Bridge 1009

The distribution across the deck for this bridge was very similar to that for bridge 996.

The stresses over the bent, however, were lower than those in bridge 996. This is undoubtedly due to a proportionally greater vertical movement of the bent under load. This movement was measured in connection with the stringer deflection measurements, and a maximum vertical movement of bent 13 was recorded of 0.19 in. When this maximum occurred, bent 12 had moved downward only 0.06 in. It seems logical to conclude that bent 13 settled enough to relieve the negative moment. The oscillograms indicate a complete reversal of stress in the stringer at this bent. It would seem that compressive stress, or at least a relief of dead-load tensile stress, on top of the stringer over the bent could occur only by settlement of the bent under load.

3. Maximum Recorded Stresses in Stringers

The maximum live load plus impact stresses recorded in the stringers of bridge 996 are shown on Figs. 6 to 11, incl., and of bridge 1009 on Figs. 12 to 17, incl. Each of these figures contains a plot of maximum tensile stresses at the various speeds for each stringer on which strain gages were placed. Stresses in the stringers are shown for the center of two adjacent spans and over the intermediate bent. Separate graphs are shown for the two types of diesels used. The calculated values indicated are based on the assumptions outlined under Art. 1, preceding.

Bridge 996

All of these graphs indicate that the stresses in the outside stringers were much less than in the inside stringers and that the stringers carrying the largest stress are toward the center of track. This distribution of stress is somewhat parabolic, as is indicated on Figs. 4 and 5. It is apparent also that in many cases there was an increase in stress with an increase in speed and that except for gage 10, Fig. 11, all recorded stresses were less than the calculated static stresses.

Figs. 6 and 7 indicate the maximum stresses in span 3 and that the stringer with gage 26 had higher stresses than those on either side. In looking at the plan of these stringers on Fig. 2, it will be noted that stringer 26 is continuous from span 2 and the others, 23, 24, 25 and 27, are continuous from span 4 and extend a few feet past bent 3, which provides some end restraint that stringer 26 does not have.

Figs. 10 and 11 indicate that the stress distribution between stringers for span 4 is similar to that for span 3, but the stresses were higher even though the span lengths are practically the same. This may be because only half of these stringers are continuous into span 3. The others extend slightly past bent 4, and only partial continuity is obtained there. The reduced end restraint of the stringers in span 4 permits higher positive moments and stresses. By comparing the stresses in these two adjacent spans, it appears that by extending the ends of continuous stringers past the supports the

stresses in the adjacent span are reduced. The maximum stress in span 3 was 601 psi and in span 4 was 665 psi.

Figs. 8 and 9 indicate that the stresses in the stringers over the bent were slightly less than those in the adjacent spans. The distribution between the various stringers was somewhat parabolic and similar to spans 3 and 4. It is noted that two locations indicate stresses lower than the others. The gages at these points were put on stringers that stub ended about 3 ft beyond the bent. The fact that these stub ends were stressed at this point indicates that they were participating in the total negative moment resistance over the bent. Checking of stringers is often more severe near their ends, and by extending the stringer beyond the support the checking may be confined to this length, thereby minimizing the effect in the adjacent span.

The maximum recorded total stringer tensile stress over bent 4 was 554 psi. The maximum stress in the stub end of a stringer was 195 psi.

Bridge 1009

These graphs indicate trends similar to those for bridge 996, namely, a parabolic distribution of stress between stringers, the outside stringers carrying very little stress, and an increase in stress with an increase in speed.

Figs. 12 and 13 indicate the maximum stresses in span 12 and Figs. 16 and 17 the maximum stresses in span 13. It is very apparent that the stresses in span 13 were higher than in span 12 even though the span lengths are the same. The explanation for this difference is possibly the same as for bridge 996: All of the stringers in span 12 are continuous from adjacent spans whereas one-half of those in span 13 are continuous into the next span and the others extend partially into this span.

The maximum stress in span 12 was 509 psi and in span 13 was 962 psi.

Figs. 14 and 15 indicate the maximum stresses over bent 13, and it is noted that these stresses are less than those in the adjacent spans. The reason for these low stresses was discussed under Art. 2, preceding. However, it is also noted that the stresses in the stub ends of these stringers that extended a few feet beyond the bent are nearly as high as the fully continuous stringers. Stub end 17 is stressed nearly as high as stringers 16 and 18, similarly for stub end 20.

The maximum stress over bent 13 was 368 psi. The maximum stress in the stub end of a stringer was 264 psi.

4. Total Impacts in Stringers

The recorded total impacts in the stringers of bridge 996 are shown on Fig. 18 and of bridge 1009 on Fig. 19. The impacts are shown as a percentage of the average recorded static stresses at the centers of spans or at the center of the bent. The total impact percentage in each test run for a particular speed and locomotive is the increase in stress in the member over the average stress occurring at speeds of about 10 mph and less.

The recorded impacts are shown for only two of the continuous stringers in each bridge. The two stringers selected are those which had high recorded maximum stresses.

No calculated impacts are indicated since the AREA design specifications for timber bridges make no allowance for impact, and no attempt was made to separate the various effects which contribute to the total impact.

Bridge 996

It can be seen that one value of the impacts is greater than 20 percent (see Fig. 18). The maximum recorded impact was 20.6 percent which occurred under a 3000 Class locomotive at 82 mph.

There seems to be an increase in impact with an increase in speed and this was especially apparent with the 3000 Class locomotives at speeds of about 80 mph. The impacts also were higher on span 3 than at the other two locations, but there is no apparent reason why this should be so.

Bridge 1009

Impacts in the stringers of this bridge were noticeably higher than in bridge 996. Most of the values are less than 60 percent with a few exceeding this. A maximum of 100 percent was recorded under the 1600 Class locomotive at 53 mph.

There was a general increase in impact with an increase in speed, but the maximum impact did not occur at highest speeds.

These high impacts may be the result of relatively large vertical movements of bent 13 with respect to the adjacent bents.

5. Maximum Stresses in Piles

The recorded maximum stresses in the piles of bent 4 for bridge 996 and bent 13 for bridge 1009 are shown on Figs. 20 and 21. Four gages were placed on each of the six piles as shown. The average of these four gages are indicated as the average maximum stress in each pile for the particular locomotive and speed.

Also shown on these figures are calculated values based on the assumptions of Art. 1 preceeding, using the measured pile diameter.

It can be seen that recorded stresses of some individual piles were higher than the calculated stresses. However, the average recorded stresses of all piles in a bent agree closely with the calculated values.

Bridge 996

The diagrams on Fig. 20 indicate that the stress distribution between piles was somewhat parabolic as was the case with the distribution between stringers. The outside piles carried the least stress and the highest stress occurred on the two center piles. It is evident that this 14- by 14-in cap is not sufficiently stiff to effect a uniform distribution to the piles since the load distribution to the piles was similar to the distribution to the stringers.

The maximum average stress in a pile at this bent was 171 psi. The average pile diameter at the gages was 13.0 in for a cross sectional area of 133 sq in. The maximum total load in the pile from the 3000 Class locomotive was 11.4 tons.

Bridge 1009

It can be seen from the diagrams on Fig. 21 that the distribution to the six piles was not the same as at bridge 996. The three piles on the left side of this bent have a parabolic distribution, but the three piles on the right side do not. It is apparent that the pile 49–52 was not carrying its share of the load as evidenced by its low stresses. The outside pile in this case was carrying as much load as an inside pile. The cut-off of pile 49–52 may have been lower than the others, making it necessary for the cap to deflect before this pile could take any load.

The maximum average stress in a pile of this bent was 184 psi. The average pile diameter at the gages was 13.1 in for a cross-sectional area of 139 sq in. The maximum recorded total direct load in the pile from the 3000 Class locomotive was 12.8 tons.

6. Recorded Stress in Sway Braces

The recorded stresses in the sway braces of bent 4 at bridge 996 and in bents 11 and 13 at bridge 1009 are shown on Fig. 22.

Strain gages were placed on the edges of the braces near the cap end, as shown, and recorded as a single strain to provide an average value.

The maximum recorded tension and compression stresses are plotted for each particular speed and locomotive. After a representative number of runs had been obtained with the bracing bolts tight, the bolts were loosened and a few runs thus recorded. Separate plots are presented with tight and loose bracing bolts.

With the bracing bolts tight there was a slight increase in stress with an increase in speed. It is also noted that the highest stresses were tensile. Since there was unequal distribution of load to the piles with the center piles carrying most of the load, it is possible that interaction between the piles and the bracing stressed these braces in tension. Much of the bracing stress undoubtedly resulted from the lateral movement of the bents, however.

With bracing bolts loose there was a noticeable reduction in stress, but the bracing continued to carry some stress.

The maximum recorded stress in the bracing was a tension of 73 psi. On a 4¼-by 8-in section this is equivalent to a load of 2480 lb. The bolt size is ¾ in.

7. Recorded Deflection of Stringers

The maximum recorded net deflections of a stringer in span 3 at bridge 996 and in span 12 at bridge 1009 are shown on Fig. 23.

The net deflections are the deflections of the stringers after correcting for the vertical movements of the supports. This correction was obtained by subtracting from the vertical movement of the center of the stringer, the average of the vertical movements of the ends of the stringer. It was found in many cases that the vertical movement of the ends of the stringer exceeded the net deflections. It is apparent that any measurements of stringer deflection must include the vertical movements of the stringer at the supports.

The deflections at bridge 996 appear to be slightly higher than at 1009. The deflections were measured at stringers 27 and 26, respectively, and it is noted on Figs. 7 and 13 that the stresses in these stringers are about the same. For simple spans it would be expected that for equal stresses the deflections would be the same, but since the degree of fixity at the supports is not known this relationship cannot be definitely established.

The maximum net deflection was recorded at bridge 996 and was 0.08 in.

8. Recorded Lateral Bent Movement

The recorded lateral bent movements in three bents at each of the bridges tested are shown on Figs. 24 and 25. The amount of movement in inches is the maximum recorded in each direction for the particular speed and locomotive. A representative number of runs were made with the bracing bolts tight, and then several runs were made after the bracing bolts had been loosened. Separate plots are shown for each condition.

All of these diagrams indicate that the bent movement definitely increased with speed. This was true whether the bracing bolts were tight or loose.

On bridge 996 the maximum bent movement of 0.10 in occurred when the bolts were tight whereas on bridge 1009 the maximum occurred with the bolts loose when the maximum movement was 0.12 in.

Apparently the bracing was not particularly effective in reducing bent movement, since there was little difference between the loose and the tight condition of the bracing.

The bents at bridge 1009 are higher than at 996 and the lateral movement at bridge 1009 was greater than at 996. As might be expected the height of the bent may be a principal factor in determining the amount of lateral bent movement.

9. Frequency of Maximum Stresses

The stresses recorded during the tests of these bridges were secured under regular scheduled trains except those few runs which were recorded at controlled speeds. These values indicate the frequency of occurrence of the maximum stresses in the stringers at various locations.

The maximum stresses recorded in one stringer of each bridge at the center of a span and at the bent are shown on the left diagrams of Figs. 26 to 29, incl.

At the upper right on these figures are shown the stress range distributions, and at the lower right these data are shown graphically. It can be seen that generally the highest stresses at each location were caused by a relatively small percentage of the locomotives crossing the bridges.

10. Maximum Recorded Stresses in Bents from Braking Across the Bridge

As previously mentioned, the regular way freight was used as a test train. This train was used to determine the effect on the structure of the train braking across the bridges at various speeds. Alternate runs were made first with the train crossing the bridge at a certain speed and then repeating the run at that speed, but crossing with a hard service application of the train and engine brakes.

Figs. 30 and 31 show the maximum recorded stresses in the piles of two bents at bridges 996 and 1009 resulting from the train crossing the bridges without braking and with braking. The stresses at individual gage locations are shown in order to determine the bending stresses in the piles. For instance, on Fig. 30, in the upper set of diagrams, stresses are shown for gages 37 and 39 when the train crossed the bridge without braking. The stress at gage 39 is higher than at 37, but this is due only to eccentricity of the direct load and probably was caused by unequal bearing of the cap on the pile, or possibly the pile was off-center with respect to the cap. Comparing the stresses for gages 37 and 39 in the upper diagram with those in the lower diagram reveals that there was no significant difference in stress. Other gage locations show a similar relationship. From these plots it can be seen that the trains braking across this bridge (but not stopping on it) produced negligible bending stresses in the piles.

11. Stresses Produced by Longitudinal Forces

The test train was also used to determine the effect on the structure of the train braking to a stop on the bridge at various positions and accelerating off it. In this series of tests, stresses were recorded at each bridge in the piles of two of the bents as close to the ground line as possible, in the rails at each end of the bridge and in the pressure cells at one end of the bridge. Runs were recorded only under southbound movements of the test train.

The general character of the stresses produced in the piles and rails by stopping and starting the test train on the bridge is shown in Fig. 32. The general elevation of bridge 1009 is shown at the top of this figure with one locomotive unit, Class 1600, and two of the five cars of the test train shown on the bridge in position.

The traces shown on the lower half of Fig. 32 were reproduced from the oscillogram secured for one of these test runs. When the train stopped on the bridge, it can be seen from the traces representing the rail gages 1 and 2 that the rails started carrying longitudinal compressive stresses when the brakes were first applied and that these

stresses kept increasing until the forward movement of the train stopped. As soon as the train stopped there was a sudden release of most of this compressive stress. It can be seen that some compressive stress remained in the rail since the trace did not return to the original base line, but this may be the Poisson's ratio effect of the approaching wheels. The compressive stresses recorded in the rails for this test run were 3429 and 3150 psi as indicated on the drawing.

During the application of the brakes and until the train stopped the greatest stress transmitted to the piles was the direct stress from the vertical load of the locomotive. This direct compressive stress reached a maximum of 78 and 97 psi in gages 57 and 58, respectively. After the train stopped there was a sudden change of stress in the piles. This change of stress resulted in a recorded compressive stress in gage 57 of — 20 psi and a tensile stress in gage 58 of + 18 psi. It can be seen that the change of stress in the piles occurred at the same instant as the release of stress in the rails.

The traces for starting on the bridge are shown in the lower right corner of Fig. 32. A short time after the train accelerated forward the rails and pile went into slight tension, as indicated by the traces. After this slight tension there was a very sharp increase in the tensile stress in the rails and a sharp release of the tensile stress in the pile. These stresses due to starting on the bridge were recorded as + 773 and + 1100 psi for rail gages 1 and 2, respectively, and — 17 and — 13 psi for pile gages 57 and 58, respectively.

The recorded stresses from braking to a stop on the bridge, as well as the direct stresses in the piles, are shown on Fig. 33 for bridge 996. The same type of data is also shown on Fig. 34 for bridge 1009, but in addition recorded traction stresses from the locomotive starting on the bridge are shown.

Bridge 996

The recorded stresses in the piles of bents 3 and 4 are shown on the left side of this tabulation. Two stress values are indicated for each run; the top figure is the maximum stress in the pile from direct load on the pile and the bottom figure is the maximum recorded bending stress in the pile from the longitudinal force. The direct stress is shown to indicate the relative magnitude of the bending stress, and it can be seen that in most cases the bending stress did not exceed the average direct stress. It is interesting to note that the bending stresses to each pile are more equally distributed than the direct stresses. Whereas under direct load, the outside pile took a small percentage of the total load to the bent, it shared about equally in resisting longitudinal forces. On several runs no value of direct stress has been shown, because the locomotive had not reached a position to produce a maximum stress in the pile.

The maximum stresses from braking occurred during run 132. It can be seen that the pile bending stresses in bent 4 averaged about 30 psi. This stress was measured at a point 4 ft 11 in below the top of cap. The average pile diameter is 13 in and its section modulus is 216 in.^{3} The force required to produce a bending stress of 30 psi in this pile is

$$P = \frac{216 \times 30}{59} = 110 \text{ lb or } 660 \text{ lb per bent.}$$

For this run, No. 132, the stresses in each rail at the south end of the bridge were — 2673 psi and — 2734 psi. Since the area of the 115 RE rail is 11.25 sq in and assuming this stress spread over the total area, the total compressive force transmitted by the rails at the south end was $(2673 + 2734) \times 11.25 = 60{,}830$ lb. At this same instant tensile stresses induced in the rails at the north end of the bridge were + 1235

psi and + 1186 psi. The total tensile force transmitted by the rails at the north end was $(1235 + 1186) \times 11.25 = 27{,}240$ lb. The total longitudinal force carried by the rails was thus 88.07 kips for this particular run. Only the first three wheels of the locomotive were on the bridge when this 88.07 kips force was recorded in the rails. Since this represents 49 percent of the total load on the bridge it is apparent that the weight of the remainder of the train also contributed to this recorded longitudinal force.

Pressure cells behind the bulkheads recorded 2.67 and 0.71 for an average of 1.69 psi during this run. This means that the bridge was being pushed against the embankment by the longitudinal force. Assuming that this pressure was distributed over a bulkhead area represented by the depth of the bulkhead and the width of the bridge deck, 4 ft by 13 ft or 52 sq ft, the total pressure was $1.69 \times 52 \times 144 = 12{,}700$ lb.

Comparing the longitudinal force carried by the rails of 88.07 kips and by the embankment of 12.7 kips and by each bent of 660 lb, it is apparent that most of the total longitudinal force from braking went into the rails.

Bridge 1009

The tabulation of values on Fig. 34 indicates a similar relation of the bending stresses to direct stresses as shown on Fig. 33. The maximum stresses from braking occurred during run 250, and the average bending stress in bent 13 was about 50 psi. This bent is about the same height as bent 4 of bridge 996, and the stress was measured at a point 4 ft 11 in below the top of cap. The average pile diameter is 13.1 in. The force required to produce this 50 psi bending stress is

$$P = \frac{220 \times 50}{59} = 187 \text{ lb or } 1122 \text{ lb per bent.}$$

During run 250 the stress in each rail at the south end of the bridge was — 3429 and — 3150 psi. The same rail section is used at this bridge as at bridge 996. The total compressive force transmitted by the rail at the south end was 74,010 lb. A tensile stress was recorded at the north end simultaneously with this, but its value could not be accurately measured since a wheel stopped over the rail gages and distorted the oscillogram trace. However, in proportion to the rail stress values of run 245, the total tensile stress was probably about + 40,050 lb. Thus, the total longitudinal force carried by the rails was about 114.06 kips for run 250. This represents 19 percent of the total weight on the bridge of the diesel unit and two loaded cars.

The pressure cells recorded pressures of 1.18 and 1.54 for an average of 1.36 psi. The total pressure on 52 sq ft of bulkhead is $1.36 \times 52 \times 144 = 10{,}200$ lb. As in bridge 996 most of the longitudinal force went down the rail.

A few tractive stresses resulting from the train starting on the bridge were recorded, as shown at the bottom of the tabulation on Fig. 34. Every effort was made to start as quickly as possible and thus induce the maximum force at the rail, but the highest stress obtained was only 1100 psi in one rail during run 250. This is only about one-third the stress from braking. It should be noted, though, that the stresses during traction are opposite to those during braking. There was also a slight relief of the compressive stress on the pressure cells, indicating movement of the bridge opposite to that during the braking runs.

It is apparent that the highest stresses from longitudinal force were the result of braking rather than traction.

12. Duration of Stress in Stringers

It has been recognized for many years that the allowable stress in timber is related to total duration of load. Because the magnitude and duration of impact or dynamic

stresses in railway trestles has been unknown, it has been standard practice to neglect these impact stresses and to design for static stresses with allowable stresses equal to those for long-time loading.

The Forest Products Laboratory has conducted investigations to determine the relation of ultimate strength to the duration of load, and in its report R1916 is shown a graph similar to Fig. 35. A similar graph also appears in the AREA Specifications for Structural Lumber, page 7–1–21 in the AREA Manual. The ordinates of this graph are percentages of working stresses to long-time loading stresses, with 100 percent indicated as "long-time loading." It can be seen that for short durations working stresses can be substantially increased.

Fig. 36 shows a typical oscillogram obtained during the test of bridge 996. In the center of this figure is shown the reproduction of part of an actual oscillogram. Only two traces are shown. The lower trace represents stress at gage 25 at center of span during the passage of a Class 1600 locomotive. The locomotive at the top of the figure is shown in the position which produced the stress indicated at point A. The upper trace represents stress at gage 18, over the center of the bent, during the passage of this same locomotive. The locomotive at the bottom of the figure is shown in position which produced the stress indicated at point B.

The two traces show the variation of live-load stress at gages 18 and 25 as the locomotive and cars crossed the trestle. The stringer on which these gages were placed is 8- by 16-in and located close to the center line of one rail. The stringer is continuous over one bent as shown. The measured stresses at gage 25 are, thus, principally tensile and result from a positive bending moment at the center of the span. The measured stresses at gage 18 are, of course, also tensile resulting from the negative bending moment over the bent. Tensile strains are indicated on these oscillograms as a downward deflection of the trace. These trace deflections are measured from a base line, or zero stress level, taken before the locomotive reaches the stringer on which these gages are placed.

In addition to stress, the oscillogram shows time duration by the timing lines at the top and bottom of the record. These lines are spaced on the actual oscillogram 0.01 sec apart, but for clarity only the 0.10 sec lines are indicated.

The two traces shown are of quite a different character. That for gage 25 indicates that after each truck has crossed the span the stress returns to zero (or slightly into compression). The trace for gage 18, however, indicates that as long as the locomotive is over the bent the stress will not return to zero, but fluctuates between a maximum tensile stress and a lower tensile stress.

The maximum static stress at gage 18 (upper oscillograph trace) is shown to be 396 psi, and this is taken to be 100 percent on the ordinate scale. For gage 25 the maximum static stress is 361 psi, with the 100 percent ordinate scale at this stress level.

These live-load stresses are, of course, quite low. It must be kept in mind, however, that the original design of this stringer included dead load, the use of simple span bending moments and a live load greater than the Class 1600 diesel. If the axle loads on Fig. 36 had been heavy enough to produce design stresses, the general shape of the oscillograph trace would have been the same as shown since the shape of the trace is primarily dependent on the axle spacing and the span length and not on the axle loads. The 100-percent static stress level can thus be considered the same as the design live-load stress.

Duration of load and stress must be associated, and it was for this reason that stress levels were established, based on the static stress, and indicated by the horizontal

lines at the 50, 60, 70, 80, 90, 100 and 110 percent ordinates of Fig. 36. The duration of stress was then determined at each gage location and at each of the above stress levels. For instance, on the lower trace the total duration of 50 percent of static stress is then the sum of line lengths a–b and c–d. For this particular run the total loading time was about 0.9 sec for the one unit. It can readily be seen that at the higher stress levels the duration of stress become much less and at the 100 percent level the loading time per unit is practically zero. On the upper trace the total duration of stress was determined similarily. However, it is apparent here that the 50 percent level of live-load stress was maintained for 1.5 sec for the full length of the locomotive.

This method of determining the duration of stress was also applied to car loading, since some oscillograms were taken under entire trains.

Two of the continuous stringers were selected from each bridge and the cumulative loading time determined for each of the two classes of locomotives and each run at the various stress levels from 50 percent to 110 percent of static stress. Three separate tabulations were made for each stringer; at the center of each span and over the center of bent. The static stress was determined for each gage location (which was also the 100 percent stress level), and this stress level was used for all runs at that gage location and for the runs involving that locomotive. An average time duration was then made at each gage location, each stress level, and for each locomotive. This average included all speeds from the static speeds of less than 10 mph to the highest speeds recorded. These average durations were plotted and appear on Figs. 37 to 40, incl.

Each plot includes curves for duration of stress for each diesel locomotive unit and each car. It can be seen that all of the curves bear a similarity to each other. As the stress level is reduced, the cumulative loading time increases. At the 100 percent and 110 percent level the loading time per unit or car is nearly zero. In several instances the duration of stress per car was zero, as for gage 18 on Fig. 38. In this case none of the cars recorded were heavy enough to equal or exceed the locomotive static stress of 516 psi and hence no time duration was recorded at stress levels higher than 80 percent.

The 24 diagrams shown on Figs. 37 to 40, incl., can be combined, and the following durations are the maximums from all the curves:

For a diesel locomotive unit:

at 110	percent of live-load design stress	= 0.07 sec
100		= 0.19
90		= 0.80
80		= 1.16
70		= 1.38
60		= 1.74
50		= 2.09

For a car:

at 110	percent of live-load design stress	= 0.09 sec
100		= 0.13
90		= 0.16
80		= 0.19
70		= 0.24
60		= 0.29
50		= 0.37

Assuming that the trains tested reasonably represent the general traffic that will be carried throughout the life of the structure, which can be assumed to be 50 years, and assuming that there will be an average of 25 trains per day each having a 3-unit locomotive and 100 cars, the total cumulative loading time in days at any stress level can be obtained by adding:

A

$$\frac{25 \times 50 \times 365 \times 3}{86{,}400} \times \text{duration for a diesel unit}$$

to

$$\frac{25 \times 50 \times 365 \times 100}{86{,}400} \times \text{duration for a car.}$$

The results are shown on Fig. 41, on which is also shown allowable stress in percent of stress for long-time loading.

It appears from Fig. 41 that an appreciable increase in allowable flexural working stresses for railway loading could be made. However, because the loading curves shown are based on only these two tests, a specific recommendation for increased stresses is not justified at this time.

H. CONCLUSIONS

The tests on these two ballasted-deck pile trestles afforded an opportunity to study the effects of static and dynamic loading on stresses in the stringers, piles and bracing under diesel locomotives at various speeds. The following statements are believed to be reasonable conclusions from the tests reported herein and are not to be construed as either final or complete for pile trestles.

The moisture content of the stringers, also of the piles and bracing, was above fiber saturation when tested, reflecting the climatic conditions at that location and season.

Stringers

1. Static Stresses

Timber bridges are currently designed under AREA specifications on the basis of static loading; hence the static live-load stresses measured are of particular interest. In general, maximum static stresses in stringers were found to be below those calculated for simple spans; the maximum stress in an individual stringer was 122 percent of calculated.

Live loads were not uniformly distributed, and there may be wide variation between adjacent stringers. Those beneath the track tended to carry approximately equal load, and those toward the outside to carry less load. Stringers beneath the ballast-retaining timbers carried very little live load.

The depth of ballast under cross ties in both these tests is much less than is ordinarily used and may have had an appreciable effect on distribution of load.

Neglecting outside stringers, the maximum average simultaneous static stress recorded at mid-span was only about 54 percent of calculated in one trestle and 65 percent in the other under the two-axle diesel. The assumption of concentrated wheel loads in design and the effects of continuity no doubt contributed largely to this difference between calculated and recorded stresses.

The average maximum stress over a bent in these tests was less than at mid-span.

2. Impact and Maximum Total Stresses

There was an increase in impact effect with speed. Impact up to about 20 percent of average static stress was recorded in one trestle and up to about 60 percent in the other; the latter is believed to be influenced by abnormal vertical movement of a bent under load. A few isolated stresses exceeded these values.

Maximum total stresses were generally below calculated static stresses at mid-span; however, the maximum recorded in an individual stringer was 150 percent of calculated static. Maximum total stresses over a bent were below calculated static stress at mid-span.

3. Continuous Action

Two-span stringers act partially continuous; also the overhang of stringers beyond supporting bents gives some continuous action. The staggering of joints combined with these and other factors produced a complex distribution of stress; however, the continuous action of the trestle was substantial.

4. Frequency of Maximum Stresses

Stresses approaching the maximum were produced by only a relatively small percentage of locomotive runs.

5. Duration of Stress

There appears to be no decided difference in the duration of stress at mid-span between an end span and an intermediate span.

The cumulative effect of car loading on duration of stress appears to be of greater importance than diesel locomotive loading.

The original research reported herein on duration of stress in stringers is of noteworthy interest, reflecting a basis for utilizing certain known strength qualities of wood in the design of wood bridges. The information developed indicates that consideration may be given to increase fiber stresses in bending over currently allowable working stresses for trestles subjected to ordinary traffic; however, the extent of the data presented herein does not permit any definite recommendations.

6. Deflection in Stringers

Net deflections were measured; the maximum found was 0.08 in.

Piles

Live loads were not uniformly distributed to piles. Piles toward the center line of track generally carried the largest proportion of load, piles beneath the rails carried somewhat less load, and outside piles still less.

Maximum total stress in most of the piles was approximately 125 to 175 percent of calculated average static stress, with outside piles, however, generally carrying less than the calculated stress. Corresponding values may be assumed for bearing stress of caps on piles. There did not appear to be any definite or uniform increase in stress with speed.

Vertical movement of a bent over and above normal elastic compression of the timber and soil resulted in abnormal stress distributions.

Sway Bracing

The maximum load measured in a 4- by 8-in sway brace was 2480 lb. The strength of the bolted joint necessary to carry this load is the subject of other current investigations. The measurements made in bracing may not be very significant in view of the low height of bents in these particular tests. It was noted that higher stresses were recorded in bracing when bolts were tight than when loosened, indicating the importance of keeping bolts tightened.

Lateral Bent Movements

For bents of relatively low height, sway bracing was not very effective in reducing lateral movement.

(Text concluded on page 167)

TABLE 1

SEABOARD AIR LINE TIMBER TRESTLE TEST

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES AT CENTER OF SPAN

	Diesel Locomotive		Bridge 996 Recorded Static Stresses at Center of Span (+B. M. f) *Gage Numbers										Average Calculated Static Stress	Stress Factor Max. Rec. / Avg. Calc.	
	Class	Number	5	6	7	8	9	10	11	12	13	14			Avg.
Span 4	1600	1601	75	389	407	518	178	573	197	401	382	115	722	0.794	0.82
		1601	75	410	428	554	200	607	231	417	394	114		0.841	
		1601	84	419	428	554	197	607	226	410	394	108		0.841	
		1601	80	397	407	518	179	577	207	401	386	108		0.799	
	3000	3007	75	403	444	552	192	610	175	392	395	110	641	0.952	0.94
		3032	67	406	417	539	178	596	179	406	401	118		0.930	

			*Gage Numbers 22	23	24	25	26	27	28			
Span 3	1600	1601	41	185	318	336	478	336	53	722	0.662	0.70
		1601	41	201	361	374	528	369	62		0.731	
		1601	41	201	348	377	533	364	67		0.738	
		1601	49	185	324	355	497	355	50		0.688	
	3000	3032	58	212	370	385	568	373		641	0.886	0.82
		3007	50	203	333	361	485	352	55		0.757	
		3032	46	218	333	369	519	373	62		0.810	

Bridge 1009

			*Gage Numbers 5	6	7	8	9	10	11	12	13	14			
Span 13	1600	1633	100	363	450	744	445	556	512	548	147	101	722	1.030	1.03
		1633	91	329	412	719	419	541	497	529	140	69		0.996	
		1633	90	350	447	766	456	584	535	562	162	94		1.061	
		1633	84	341	422	723	434	550	497	526	148	78		1.001	
		1633	104	360	457	763	457	575	535	556	153	87		1.057	
	3000	3028	101	378	487	738	484	578	541	563	165	96	641	1.151	1.19
		3028	134	391	509	782	484	591	544	539	154	94		1.220	

			*Gage Numbers 22	23	24	25	26	27	28			
Span 12	1600	1633	18	287	212	287	415	281	46	722	0.575	0.57
		1633	22	291	235	294	415	250	50		0.575	
		1633	25	295	218	310	419	278	46		0.580	
		1633	9	278	222	285	403	244	41		0.558	
		1633	25	309	215	304	419	269	46		0.580	
	3000	3028	22	320	235	300	403	272	63	641	0.629	0.64
		3028	25	248	210	273	419	288	63		0.654	

* See Figs. 2 and 3 for location of gages,

TABLE 2

SEABOARD AIR LINE TIMBER TRESTLE TESTS
RECORDED STATIC STRESSES AT CENTER OF BENT

	Diesel Locomotive		Bridge 996 Recorded Static Stresses at Center of Bent (-B. M. f) *Gage Numbers							Maximum Recorded +B. M. f**	Ratio of Max. (-B. M. f) / Max. (+B. M. f)	
	Class	Number	15	16	17	18	19	20	21			Avg.
Bent 4	1600	1601	241	99	407	395	46	394	41	573	0.710	0.70
		1601	243	99	395	395	59	408	49	607	0.672	
		1601	252	108	394	395	59	417	41	607	0.687	
		1601	252	112	413	398	59	429	41	577	0.744	
	3000	3032	312	132	506	499	43	524				0.88
		3007	311	115	524	524	50	503	59	610	0.859	
		3032	318	130	540	524	67	519	38	596	0.906	
Bridge 1009												
			*Gage Numbers									
			15	16	17	18	19	20	21			
Bent 13	1600	1633	50	101	115	143	115	93	75	744	0.192	0.19
		1633	25	137	110	150	153	97	59	719	0.213	
		1633	38	112	126	138	106	94	76	766	0.180	
		1633	16	128	126	150	135	101	59	723	0.207	
		1633	43	112	126	134	115	94	81	763	0.176	
	3000	3028	51	218	182	213	204	187	101	738	0.295	0.30
		3028	51	210	159	229	234	147	115	782	0.299	

* See Figs. 2 and 3 for location of gages.
**See Table I

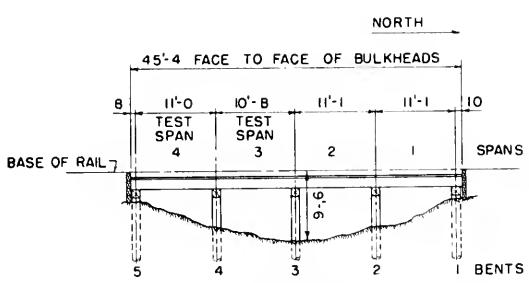
Braking and Traction

Braking and traction tests produced only minor bending stresses in piles, confirming the usual assumption that these forces may be neglected in the design of ordinary pile trestles. Most of the force was carried by the rails. Traction forces were much less than braking forces.

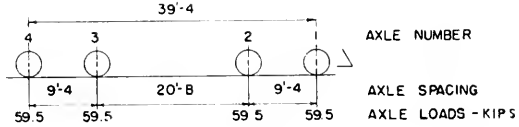
General

The test structures are capable of carrying much heavier loading than the diesel locomotives used in the tests. Unit stresses measured were generally low for this reason, and some redistribution under heavier loading can be expected.

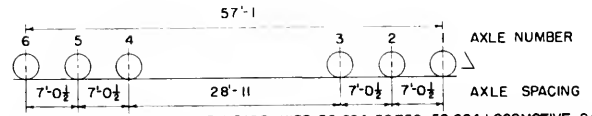
FIG 1
S.A.L. R.R TIMBER TRESTLE TEST
LOCATION OF TEST SPANS AND LOCOMOTIVE DATA



ELEVATION
BRIDGE 996, NEAR BOCA RATON, FLORIDA

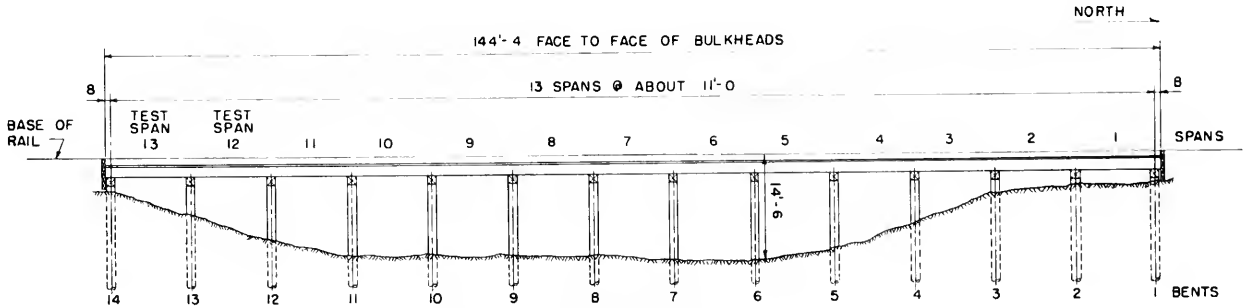


LOCOMOTIVE CLASS 1600



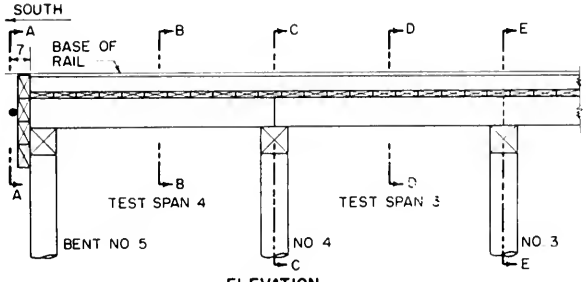
51.476 49.552 51.476 AXLE LOADS-KIPS 52.624 50.750 52.624 LOCOMOTIVE CLASS 3000
50.450 48.300 50.450 AXLE LOADS-KIPS 50.550 48.660 50.550 LOCOMOTIVE CLASS 3100

LOCOMOTIVE CLASS 3000 & 3100

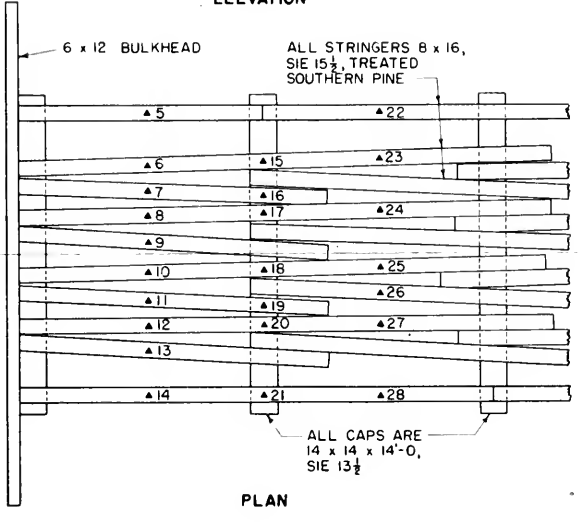


ELEVATION
BRIDGE 1009, NEAR FT. LAUDERDALE, FLORIDA

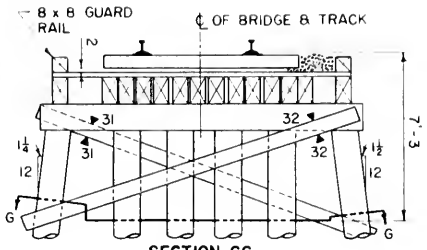
FIG. 2
S.A.L. R.R TIMBER TRESTLE TEST
LOCATION OF GAGES
BRIDGE 996



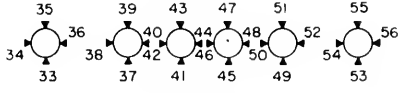
ELEVATION



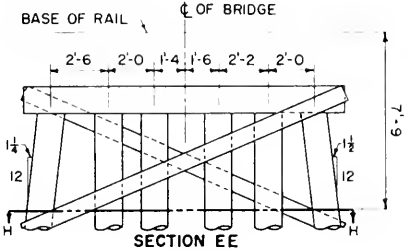
PLAN



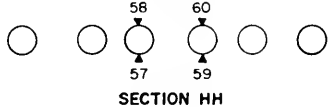
SECTION CC

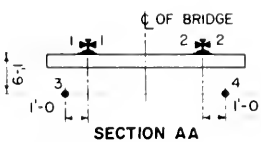

SECTION GG

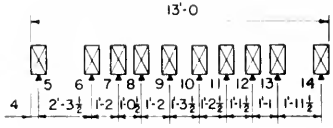
SEE FIG. 30 FOR SPACING OF PILES ON BENT NO 4

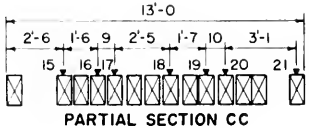


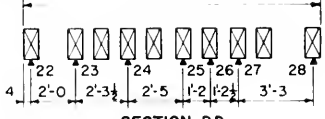
SECTION EE

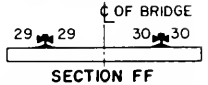

SECTION HH




SECTION BB


PARTIAL SECTION CC


SECTION DD



SECTION FF IS 1'-3 NORTH OF NORTH BULKHEADS

SYMBOLS: ▲ SR4 STRAIN GAGES
● PRESSURE CELLS

FIG 3
S.A.L. R.R TIMBER TRESTLE TEST
LOCATION OF GAGES
BRIDGE 1009

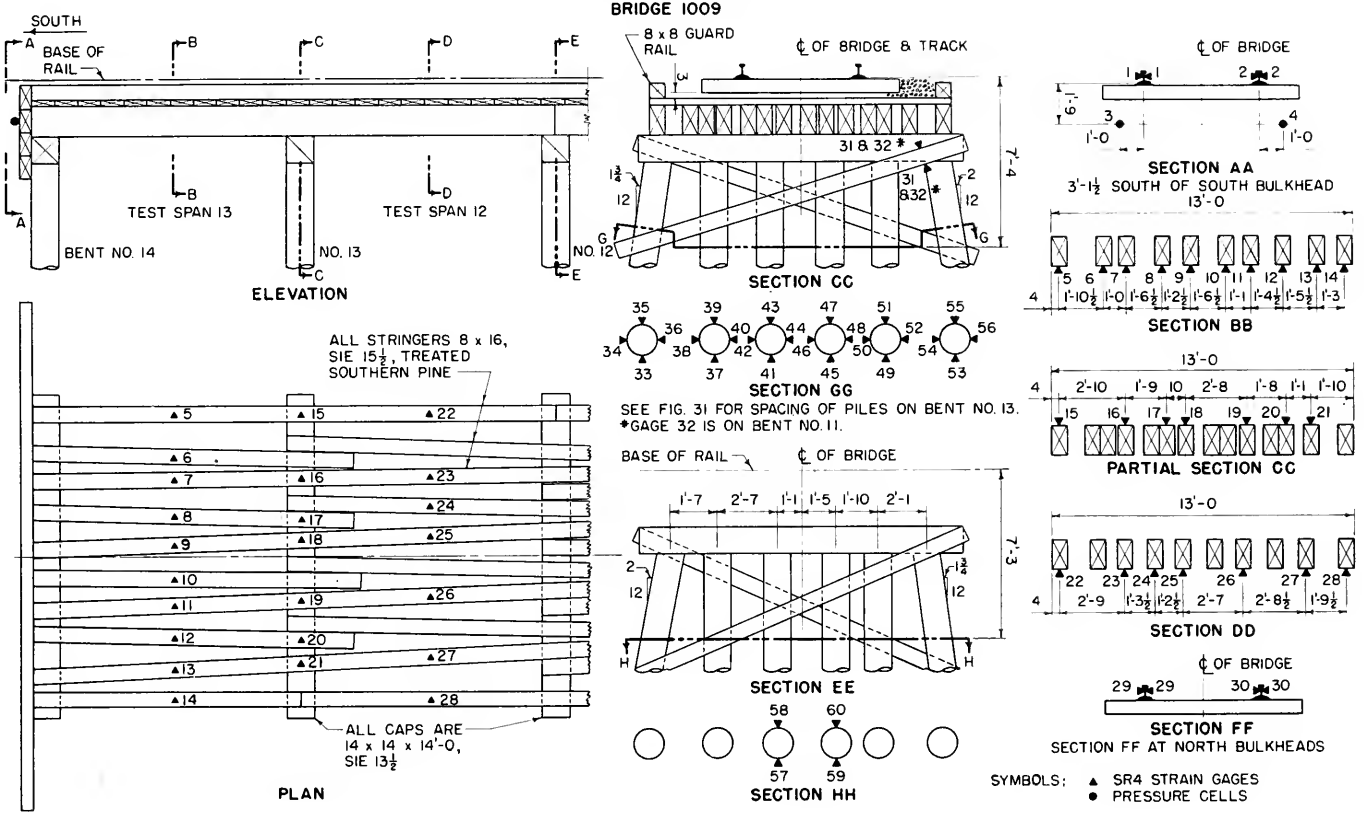


FIG. 4

S A L R R TIMBER TRESTLE TEST

SIMULTANEOUS MAXIMUM RECORDED STRESSES IN STRINGERS

BRIDGE 996-LOCOMOTIVE CLASS 1600

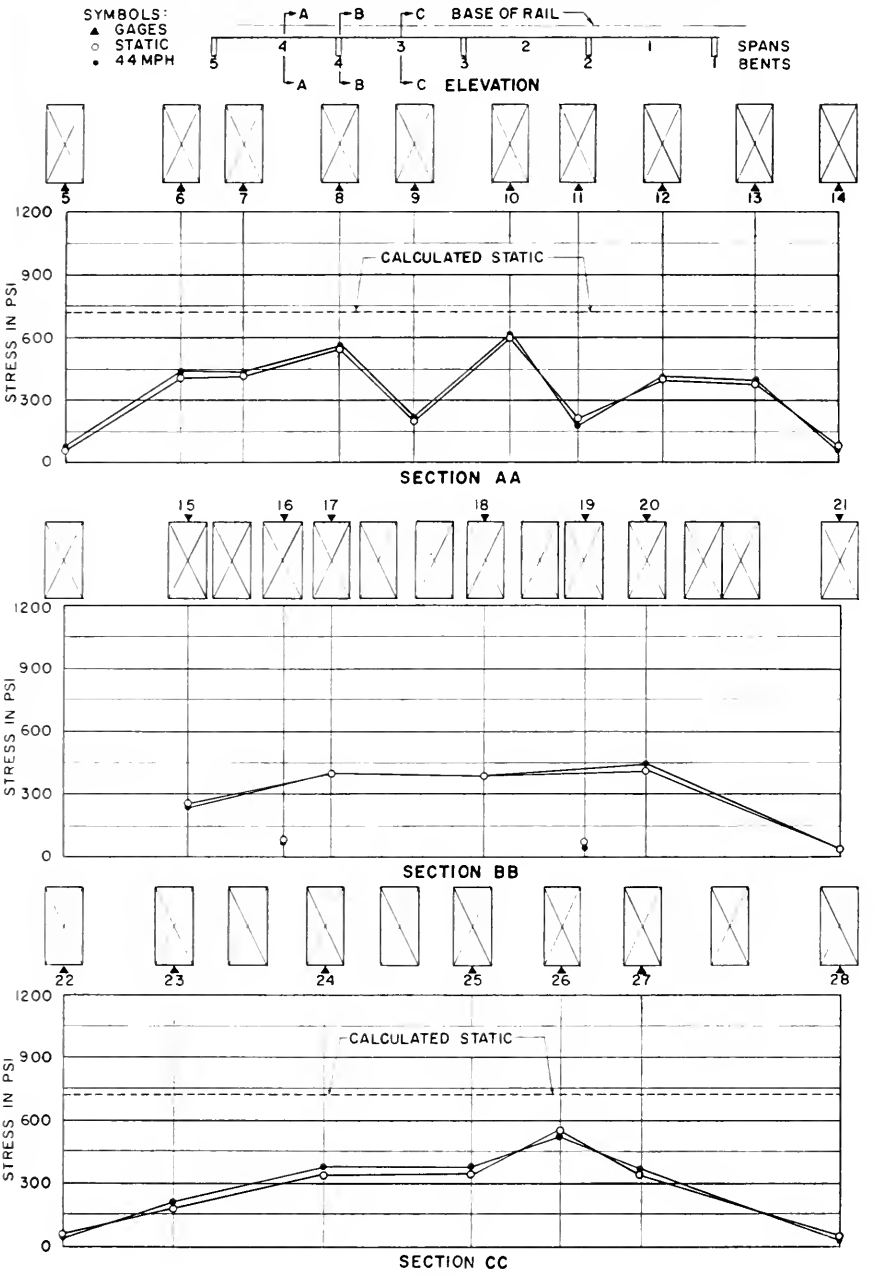


FIG. 5

S.A.L. R.R. TIMBER TRESTLE TEST

SIMULTANEOUS MAXIMUM RECORDED STRESSES IN STRINGERS

BRIDGE 1009—LOCOMOTIVE CLASS 1600

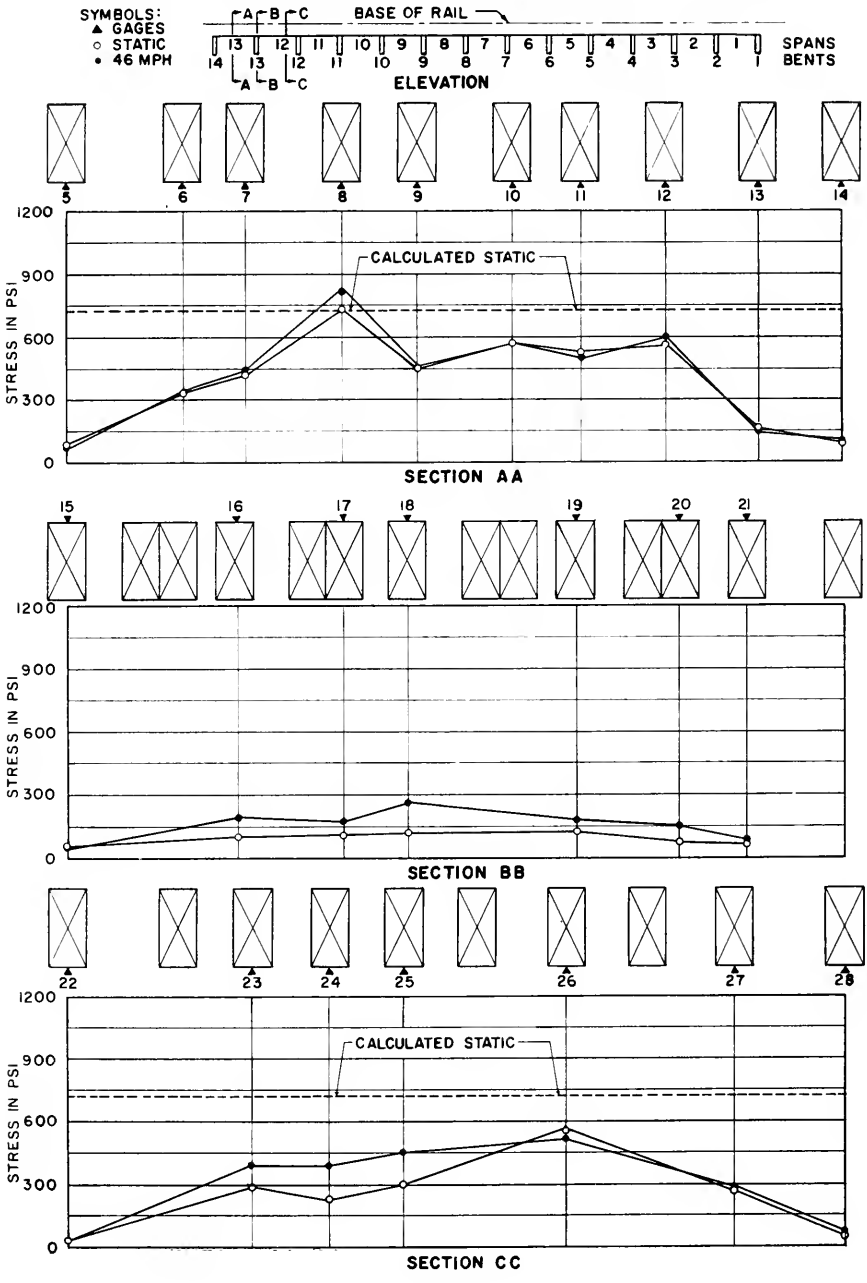
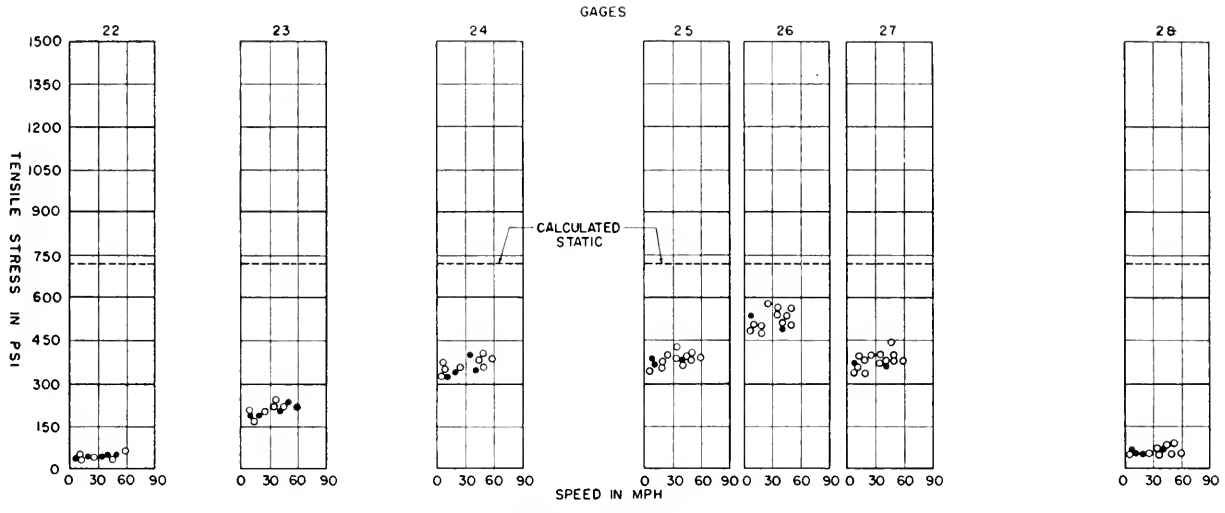


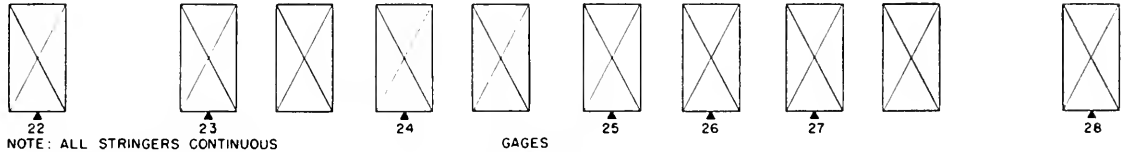
FIG. 6
S. A. L. R. R. TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 996 - SPAN 3



LOCOMOTIVE CLASS 1600

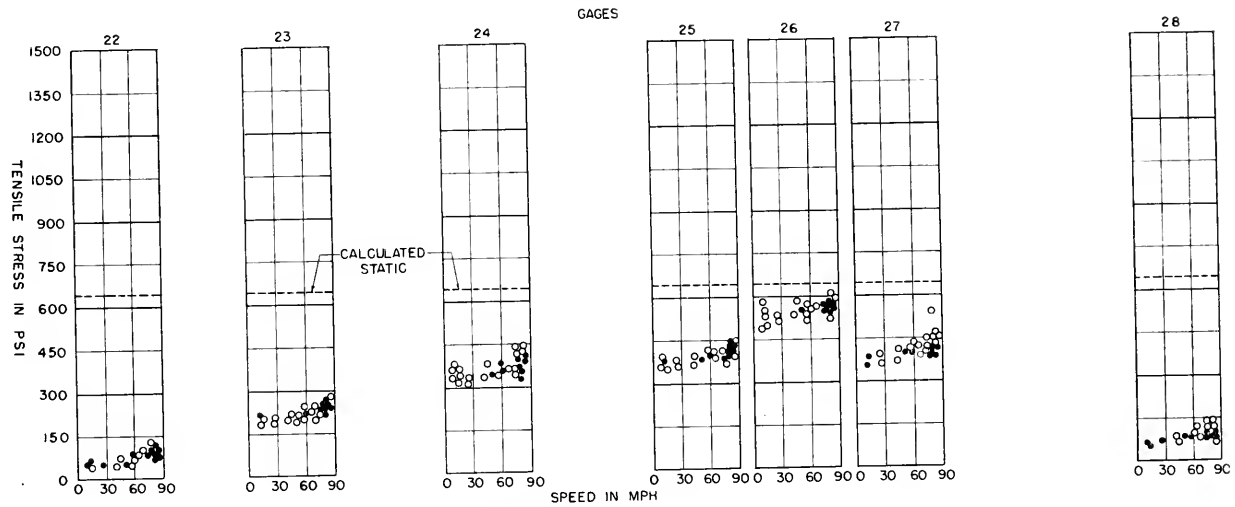


NOTE: ALL STRINGERS CONTINUOUS OVER 2 SPANS

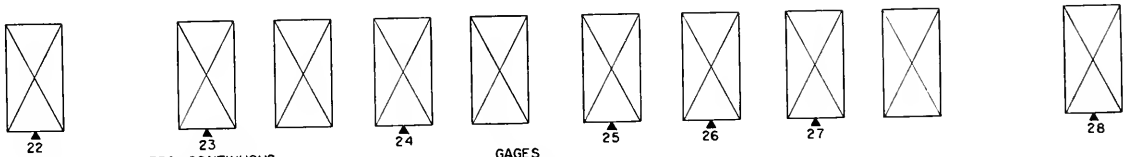
○ SINGLE VALUE
● SEVERAL VALUES

SECTION AT ℄ OF SPAN 3

FIG. 7
S. A. L. R R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 996 - SPAN 3



LOCOMOTIVE CLASS 3000 & 3100



NOTE: ALL STRINGERS CONTINUOUS OVER 2 SPANS
o SINGLE VALUE
• SEVERAL VALUES

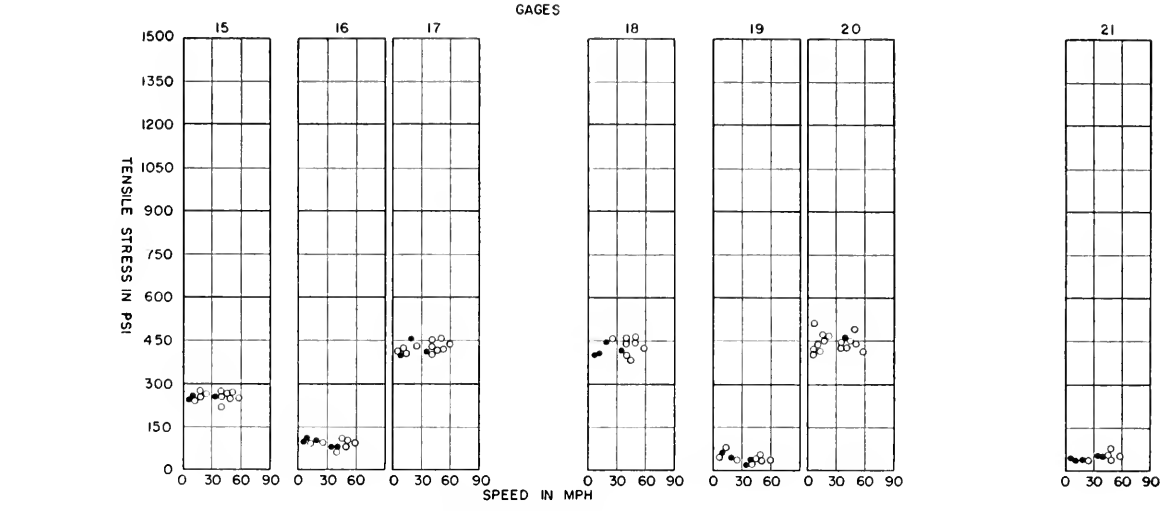
SECTION AT ℄ OF SPAN 3

FIG. 8

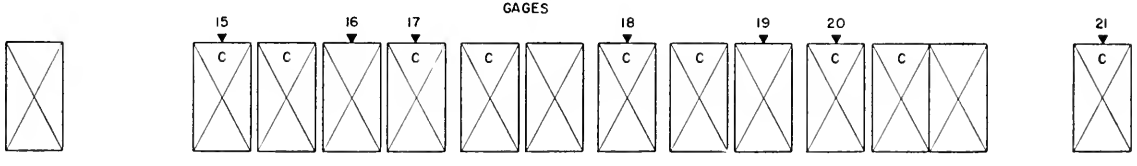
S. A. L. R. R. TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 996 - BENT 4



LOCOMOTIVE CLASS 1600

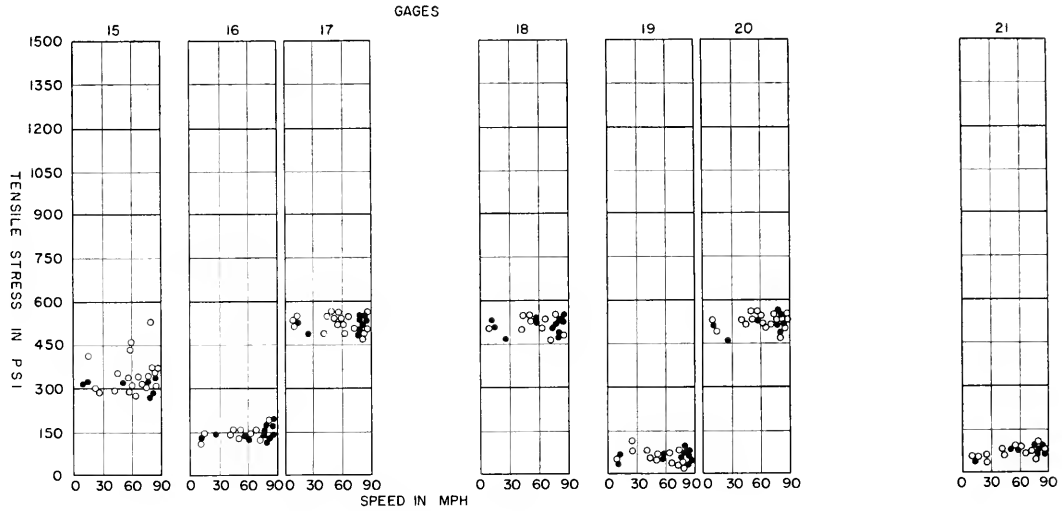


NOTE: "C" CONTINUOUS OVER 2 SPANS

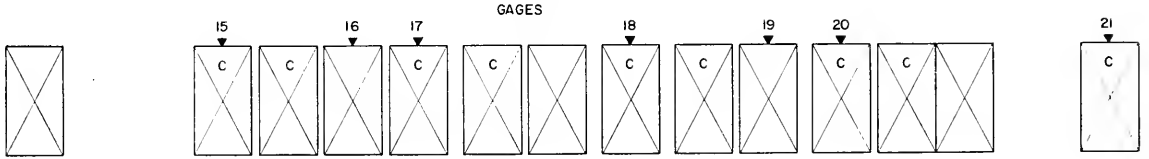
- ○ SINGLE VALUE
- ● SEVERAL VALUES

SECTION AT ℄ OF BENT 4

FIG. 9
S. A. L. R. R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 996 - BENT 4



LOCOMOTIVE CLASS 3000 & 3100



NOTE. "C" CONTINUOUS OVER 2 SPANS
o SINGLE VALUE
• SEVERAL VALUES

SECTION AT ℄ OF BENT 4

FIG 10
S A L R R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 996 - SPAN 4

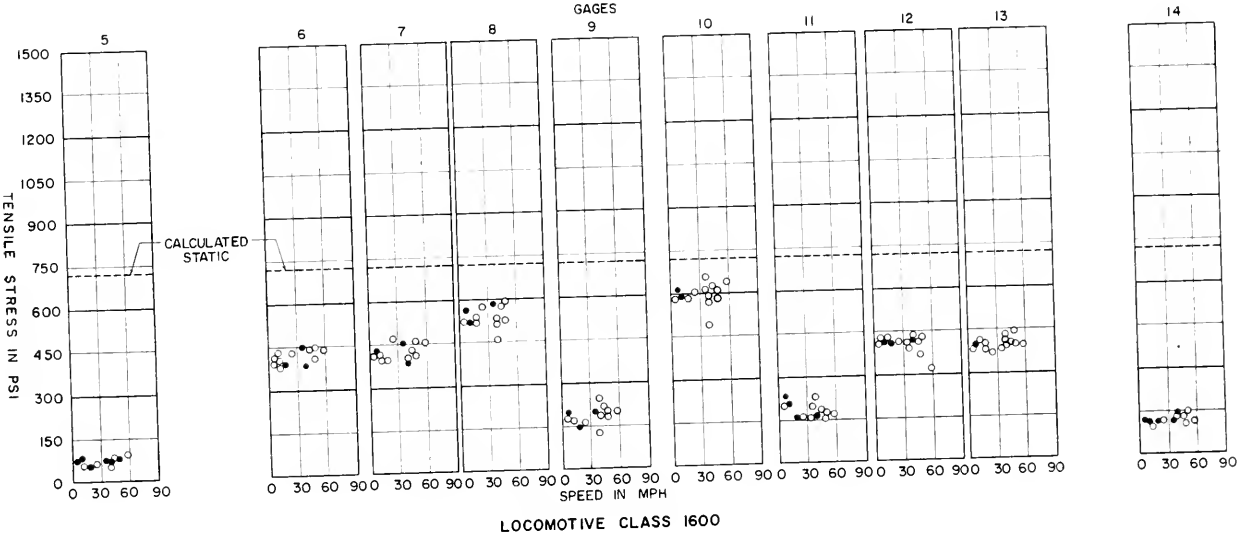
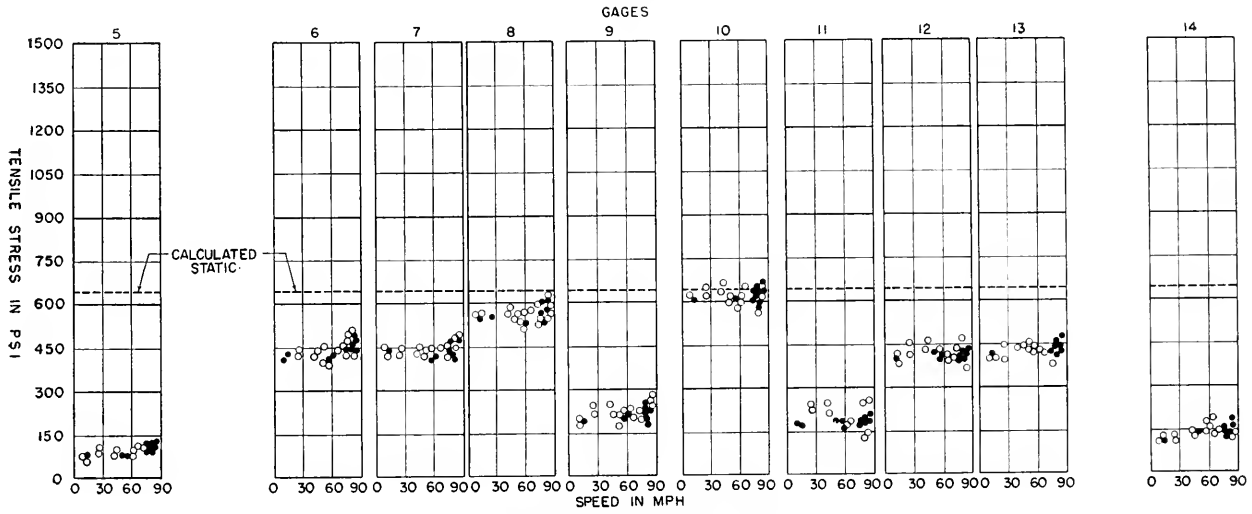


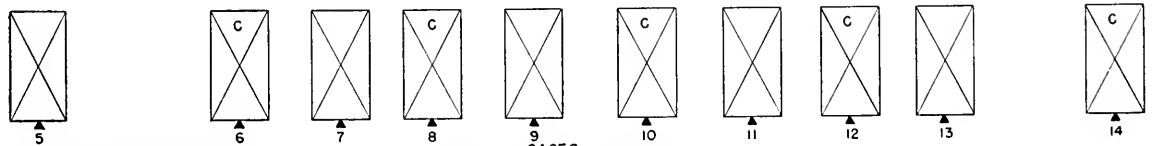
FIG 11
S A L R R TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 996 - SPAN 4



LOCOMOTIVE CLASS 3000 & 3100



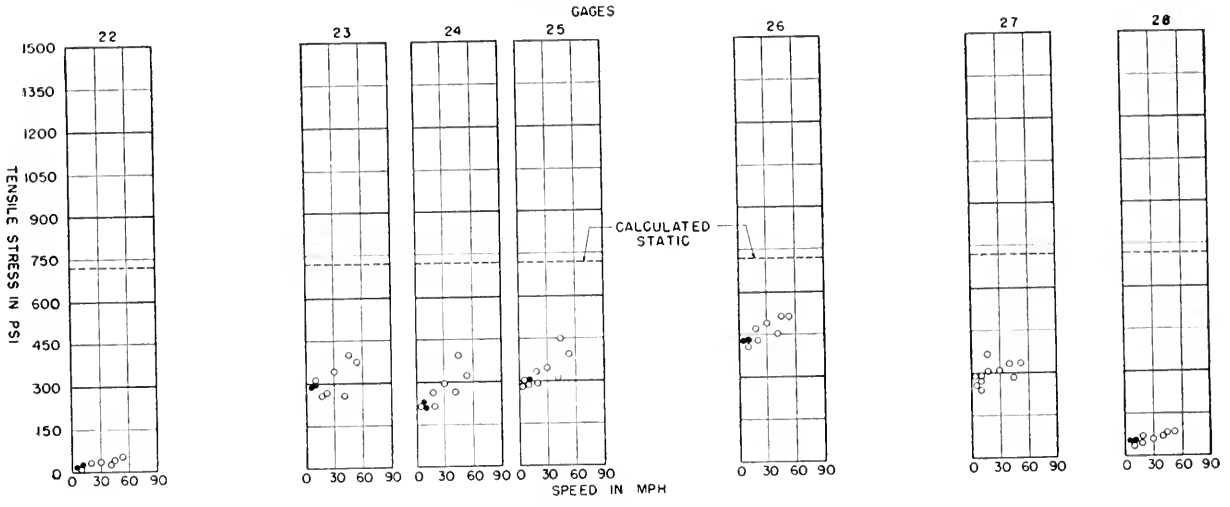
NOTE "C" CONTINUOUS OVER 2 SPANS
o SINGLE VALUE
● SEVERAL VALUES

SECTION AT ℄ OF SPAN 4

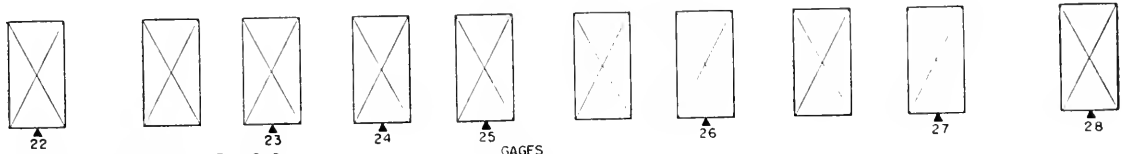
FIG 12
S A L R R TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 1009 - SPAN 12



LOCOMOTIVE CLASS 1600



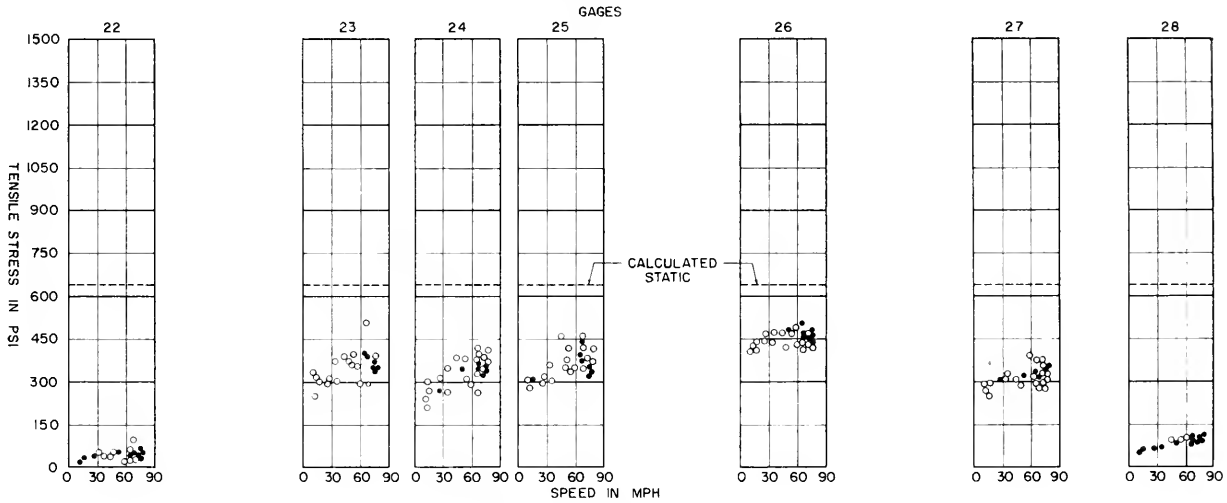
NOTE: ALL STRINGERS CONTINUOUS OVER 2 SPANS
○ SINGLE VALUE
● SEVERAL VALUES

SECTION AT ℄ OF SPAN 12

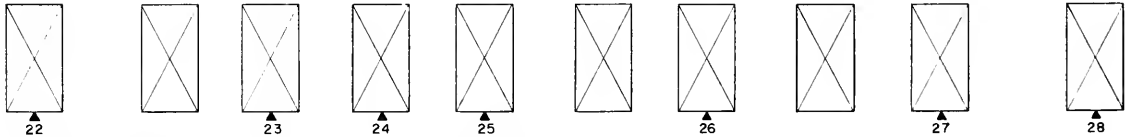
FIG 13
S A L R.R. TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 1009 - SPAN 12



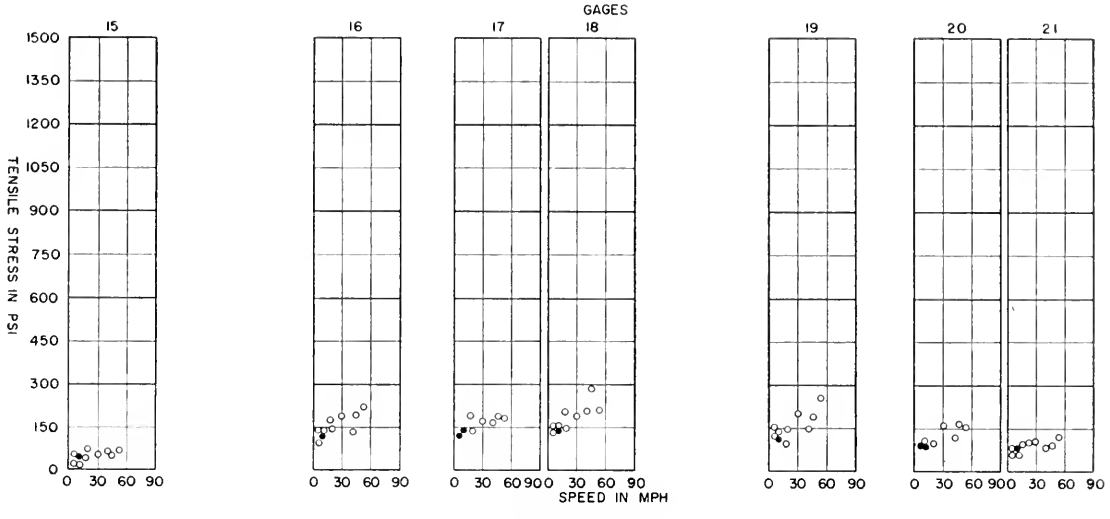
LOCOMOTIVE CLASS 3000 & 3100



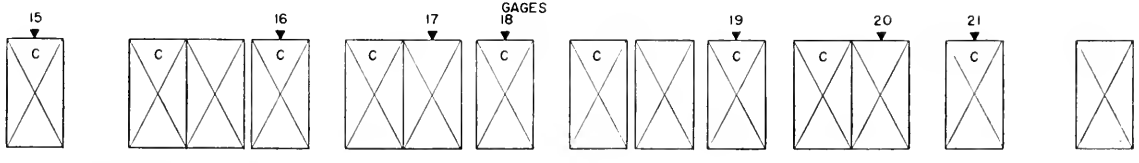
NOTE: ALL STRINGERS CONTINUOUS OVER 2 SPANS
○ SINGLE VALUE
● SEVERAL VALUES

SECTION AT ℄ OF SPAN 12

FIG. 14
S.A.L. R.R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 1009 - BENT 13



LOCOMOTIVE CLASS 1600



NOTE: "C" CONTINUOUS OVER 2 SPANS
○ SINGLE VALUE
● SEVERAL VALUES

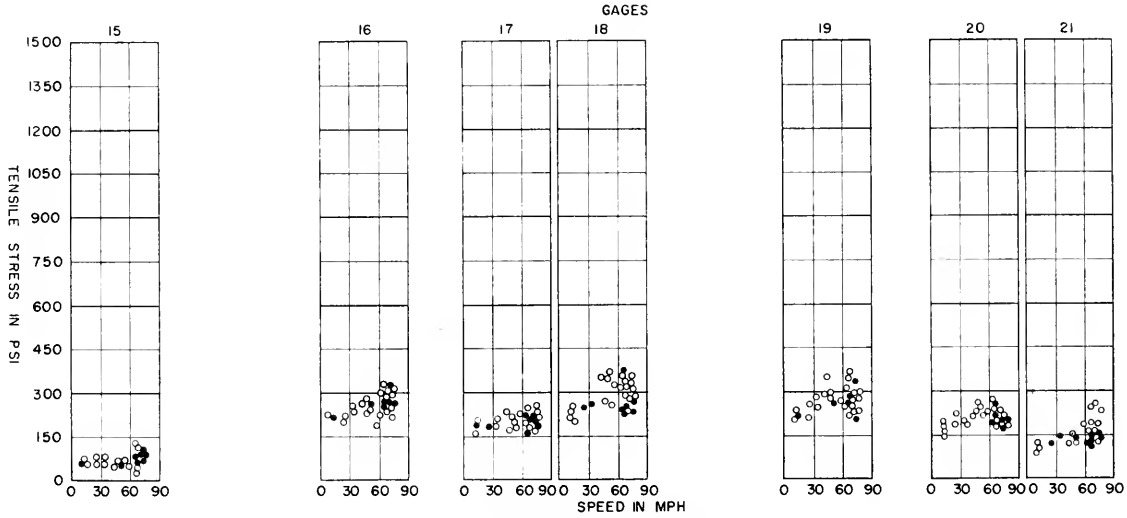
SECTION AT ℄ OF BENT 13

FIG. 15

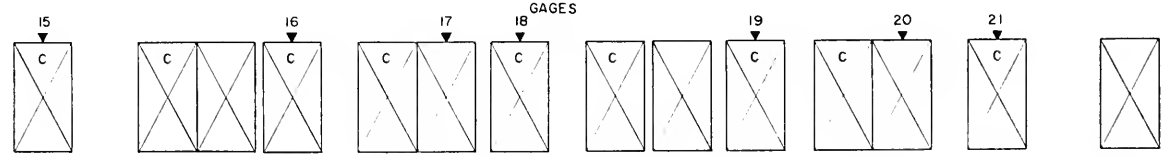
S. A. L. R. R. TIMBER TRESTLE TEST

MAXIMUM RECORDED STRESS IN STRINGERS

BRIDGE 1009 - BENT 13



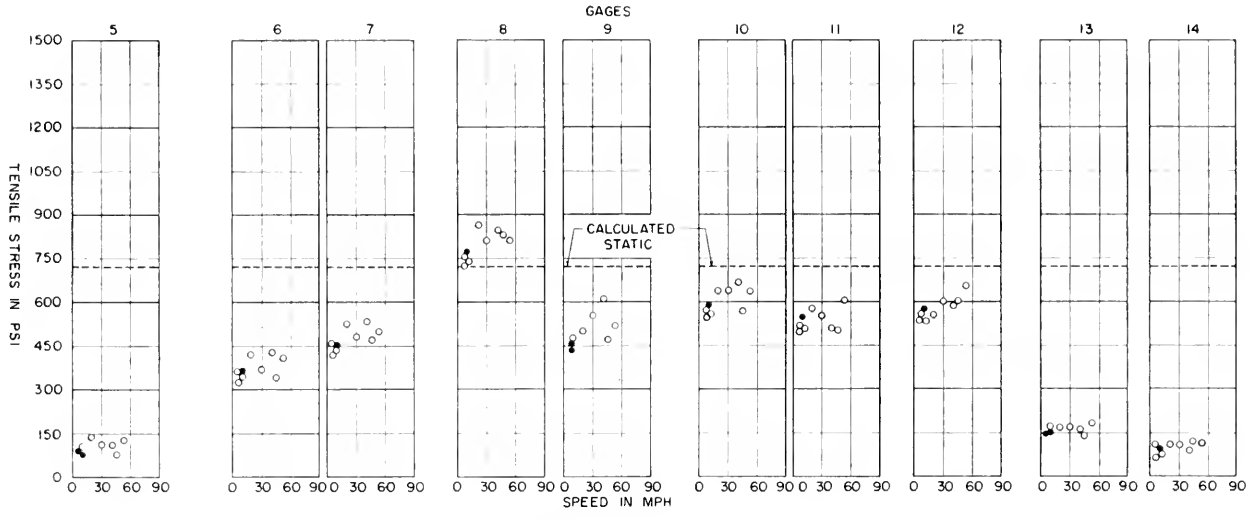
LOCOMOTIVE CLASS 3000 & 3100

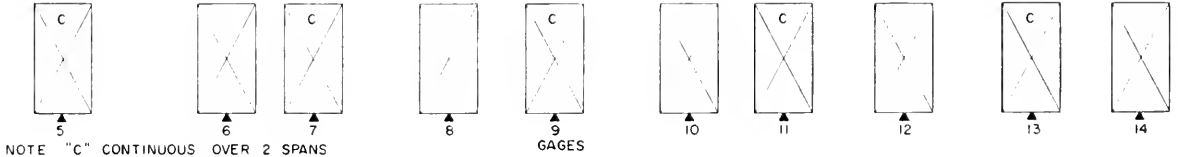


NOTE: "C" CONTINUOUS OVER 2 SPANS
o SINGLE VALUE
• SEVERAL VALUES

SECTION AT ℄ OF BENT 13

FIG. 16
S. A. L. R. R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 1009 - SPAN 13

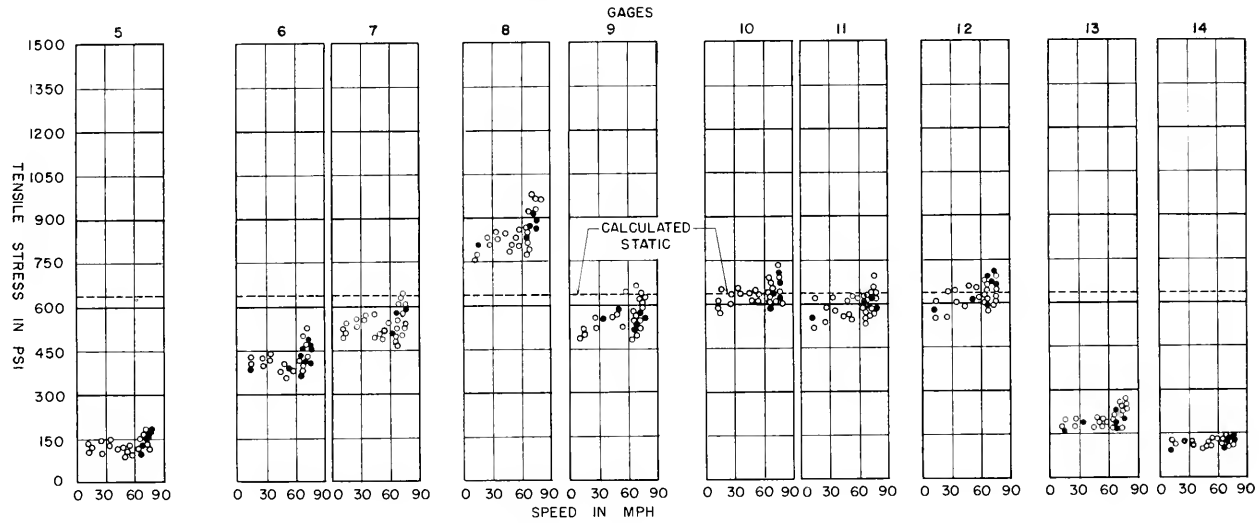




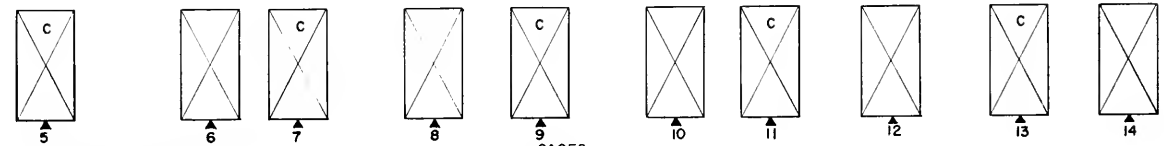
NOTE "C" CONTINUOUS OVER 2 SPANS
○ SINGLE VALUE
● SEVERAL VALUES

SECTION AT ℄ OF SPAN 13

FIG. 17
S.A.L. R.R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESS IN STRINGERS
BRIDGE 1009 - SPAN 13



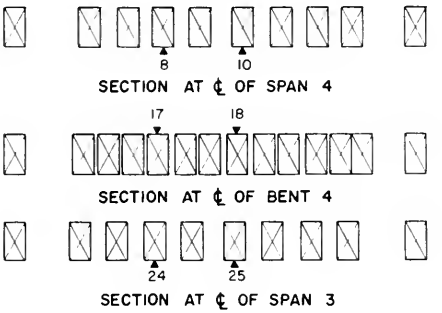
LOCOMOTIVE CLASS 3000-3100

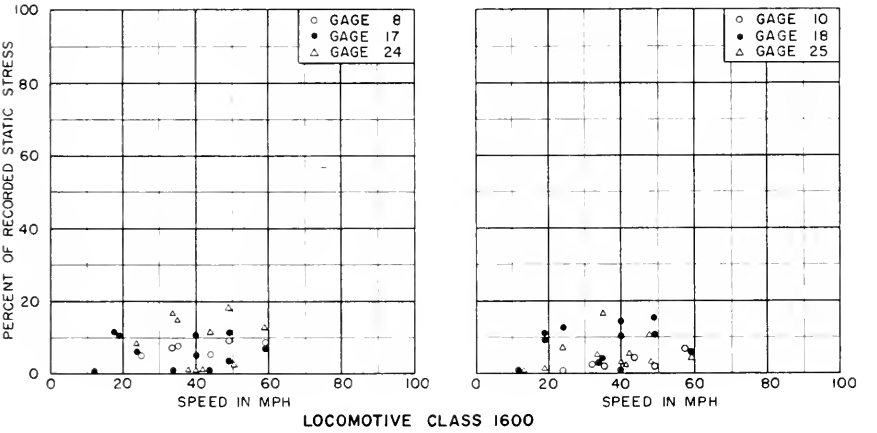


NOTE: "C" CONTINUOUS OVER 2 SPANS
○ SINGLE VALUE
● SEVERAL VALUES

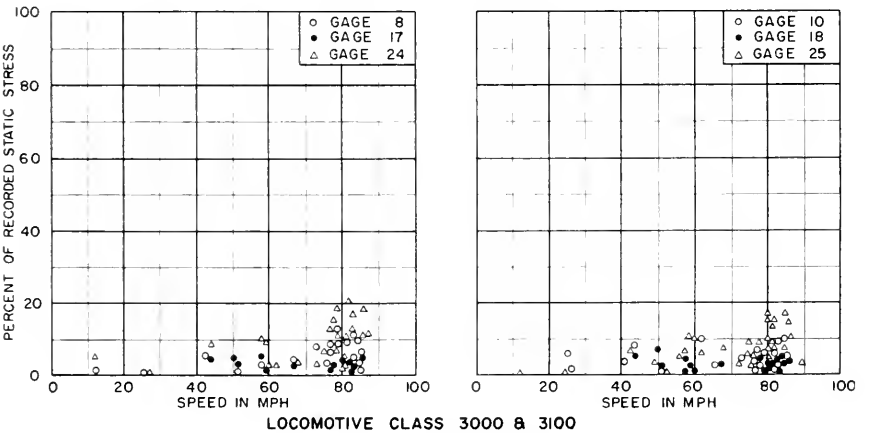
SECTION AT ℄ OF SPAN 13

FIG 18
S. A. L. R. R. TIMBER TRESTLE TEST
RECORDED TOTAL IMPACTS IN STRINGERS
BRIDGE 996



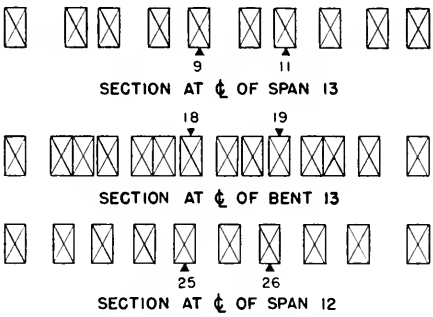


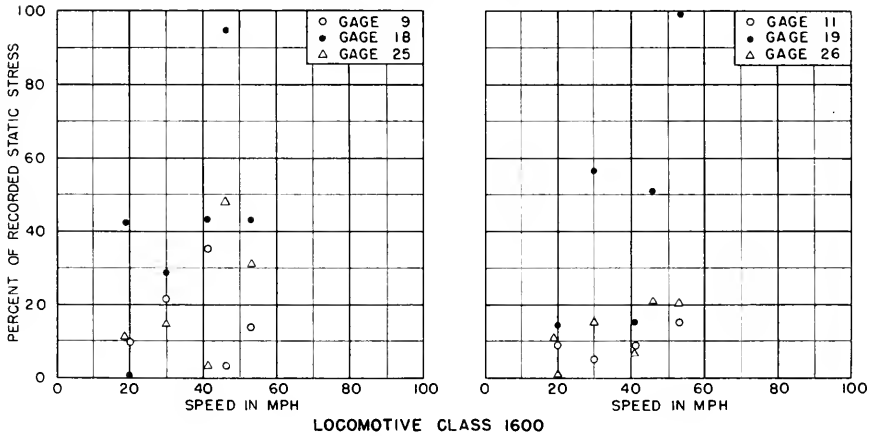
LOCOMOTIVE CLASS 1600



LOCOMOTIVE CLASS 3000 & 3100

FIG. 19
S. A. L. R.R. TIMBER TRESTLE TEST
RECORDED TOTAL IMPACTS IN STRINGERS
BRIDGE 1009





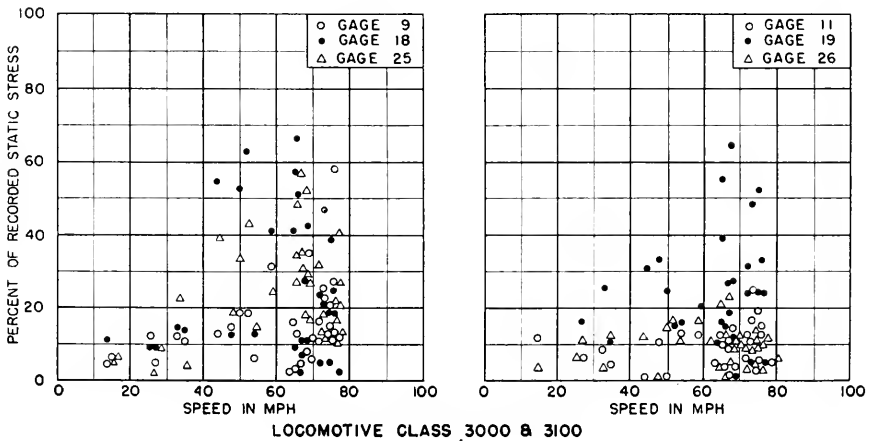
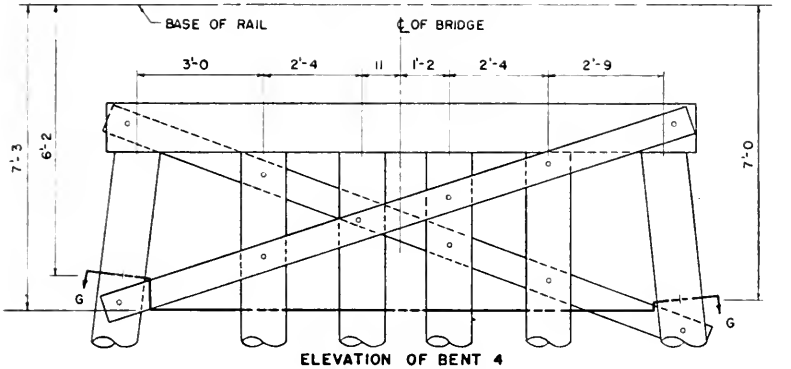
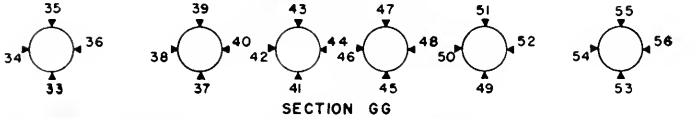


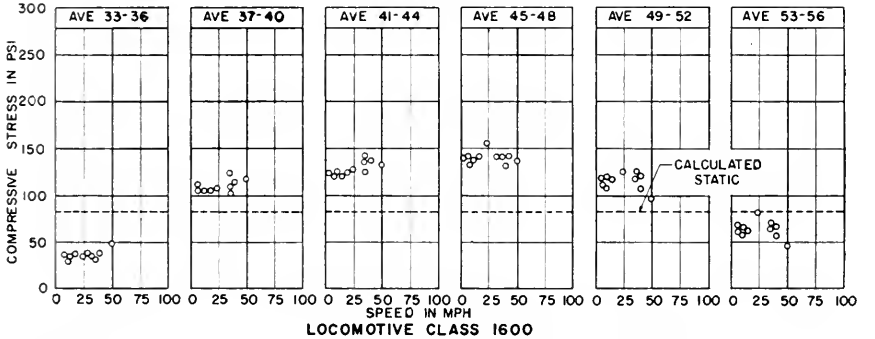
FIG 20
S A L. R R TIMBER TRESTLE TEST
MAXIMUM STRESSES IN PILES
BRIDGE 996-BENT 4



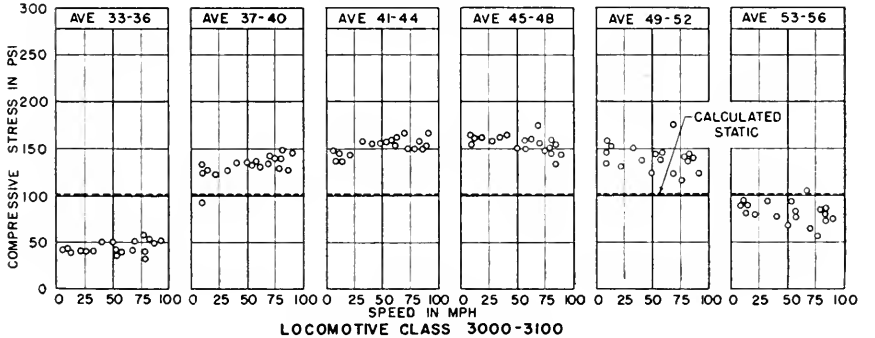
ELEVATION OF BENT 4



SECTION GG

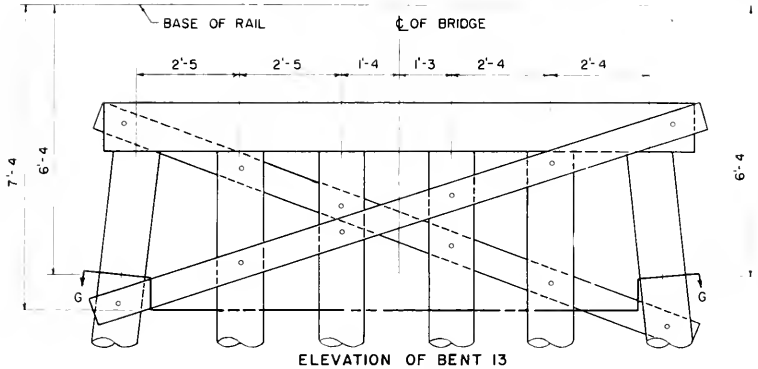


LOCOMOTIVE CLASS 1600

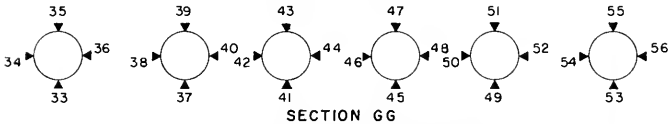


LOCOMOTIVE CLASS 3000-3100

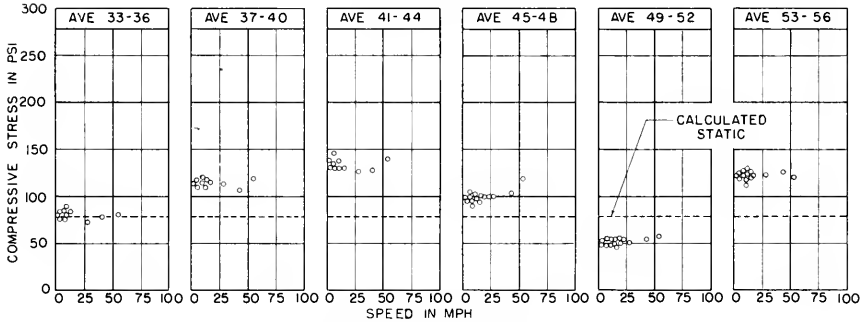
FIG 21
S.A.L. R.R. TIMBER TRESTLE TEST
MAXIMUM STRESSES IN PILES
BRIDGE 1009 - BENT 13



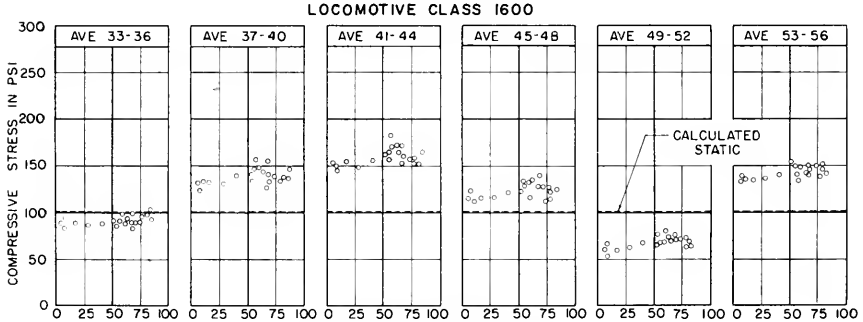
ELEVATION OF BENT 13



SECTION GG



LOCOMOTIVE CLASS 1600



LOCOMOTIVE CLASS 3000-3100

FIG 22
S A L R R TIMBER TRESTLE TEST
RECORDED STRESS IN SWAY BRACES

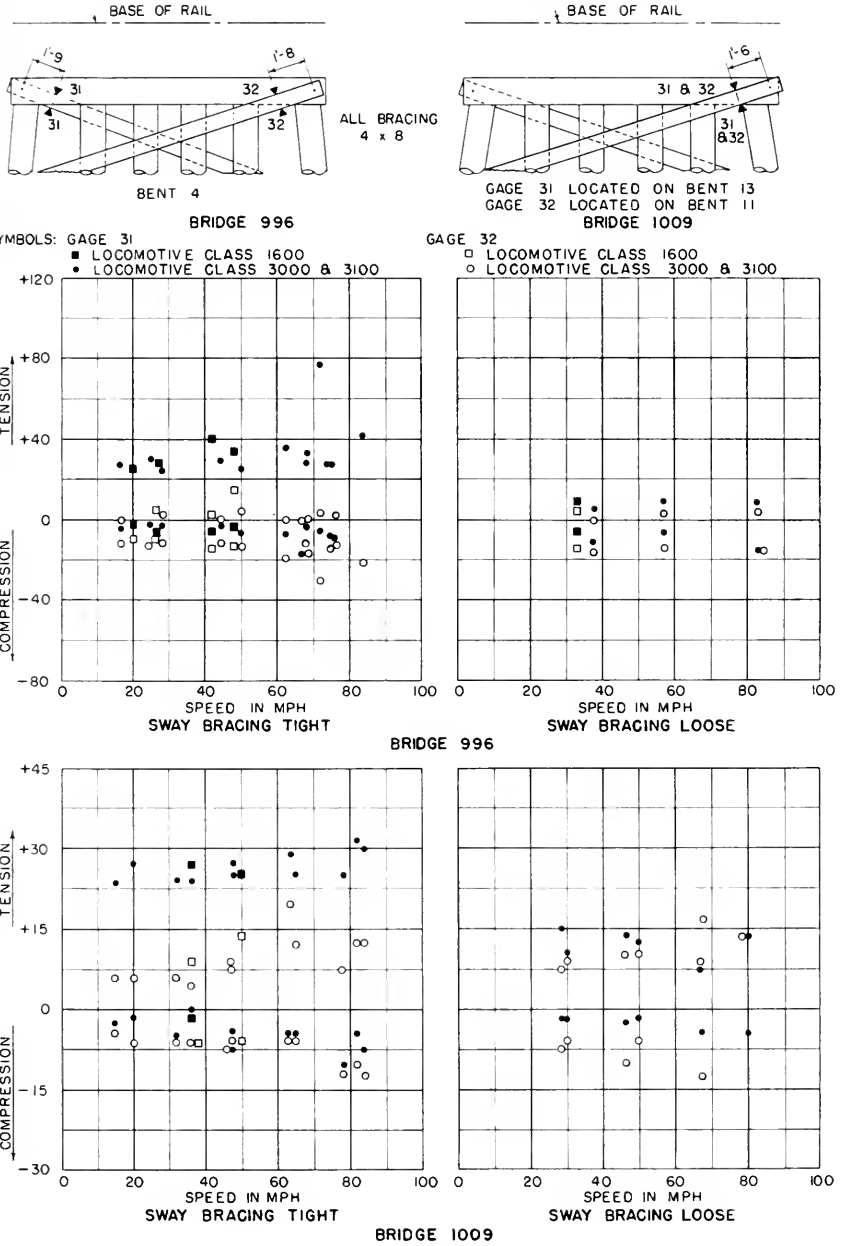
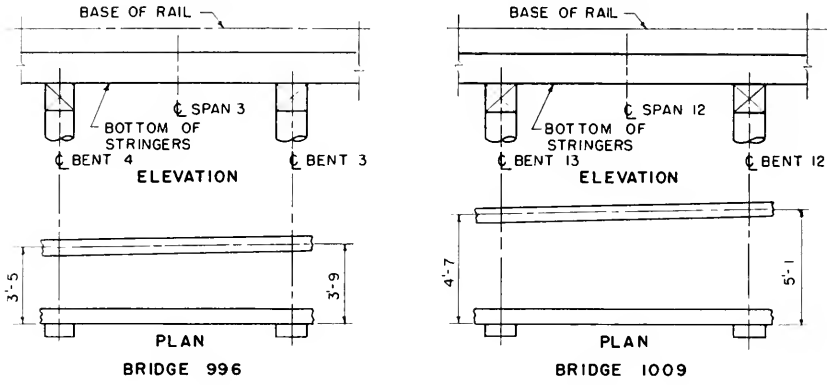
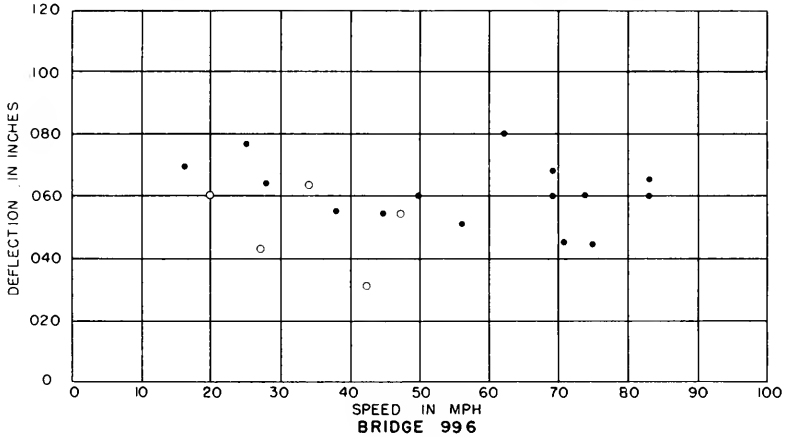
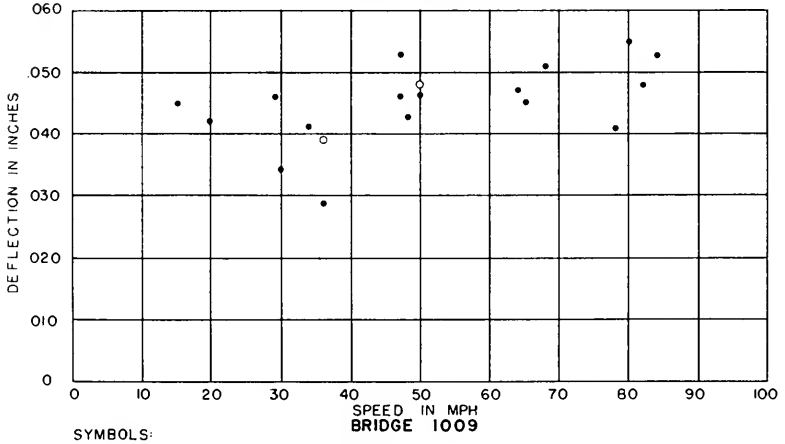


FIG. 23
S A L R R. TIMBER TRESTLE TEST
RECORDED NET DEFLECTION AT ℄ OF SPAN

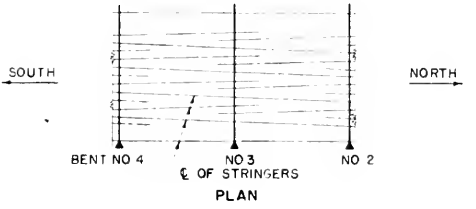




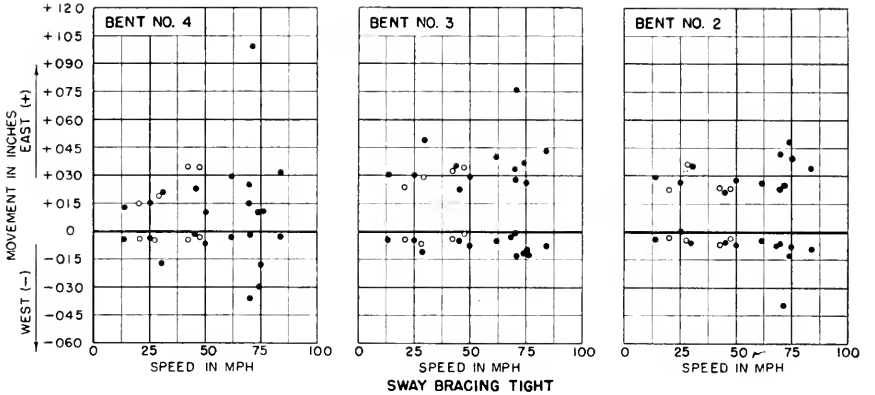


SYMBOLS:
○ LOCOMOTIVE CLASS 1600
● LOCOMOTIVE CLASS 3000 & 3100

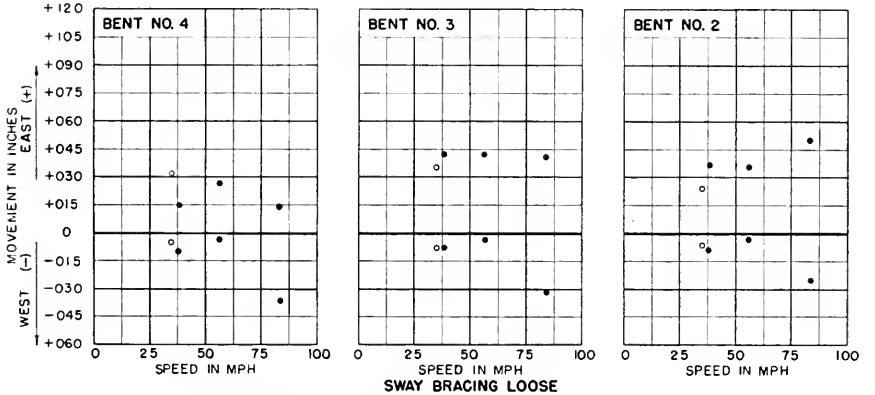
FIG 24
S A L R R TIMBER TRESTLE TEST
RECORDED LATERAL BENT MOVEMENT
BRIDGE 996



PLAN



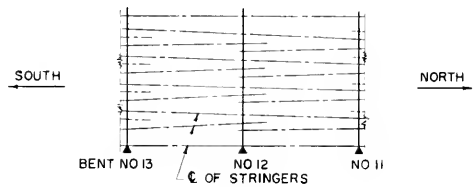
SWAY BRACING TIGHT

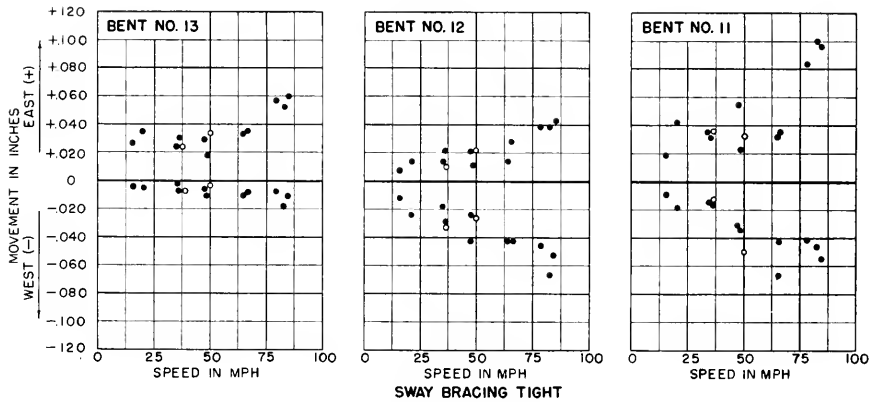


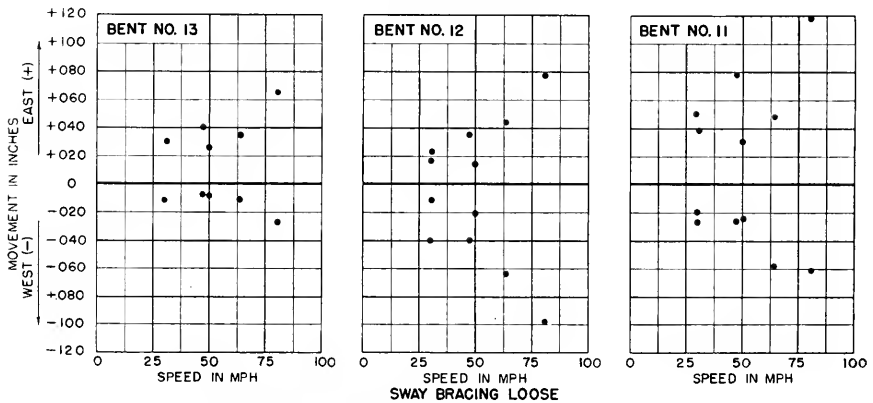
SWAY BRACING LOOSE

SYMBOLS : o LOCOMOTIVE CLASS 1600
• LOCOMOTIVE CLASS 3000 & 3100

FIG 25
S.A.L. R.R. TIMBER TRESTLE TEST
RECORDED LATERAL BENT MOVEMENT
BRIDGE 1009

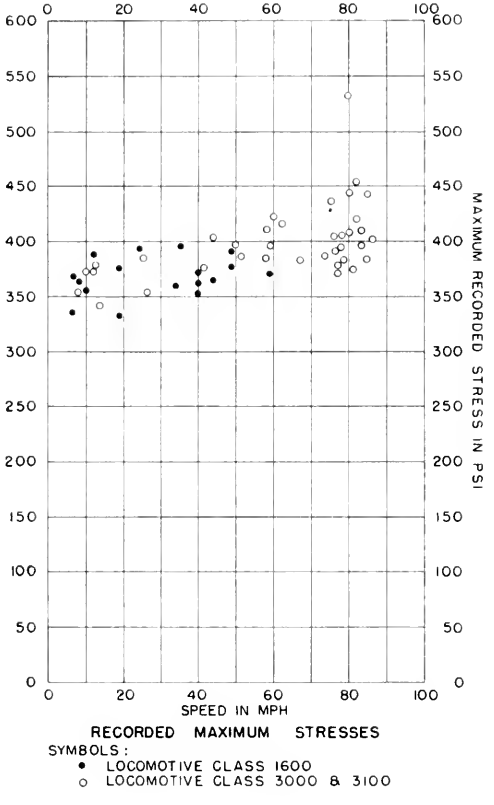






SYMBOLS: o LOCOMOTIVE CLASS 1600
• LOCOMOTIVE CLASS 3000 & 3100

FIG. 26
S. A. L. R. R. TIMBER TRESTLE TEST
FREQUENCY OF MAXIMUM STRESSES
BRIDGE 996



STRESS RANGE DISTRIBUTION
SPAN 3, GAGE 27

STRESS RANGE OF RECORDED MAXIMUM STRESS IN PSI	NUMBER OF READINGS FOR EACH STRESS RANGE			PERCENT OF TOTAL READINGS		
	LOCO. CLASS			LOCO. CLASS		
	1600	3000 3100	TOTAL	1600	3000 3100	TOTAL
520 TO 539		1	1		1.9	1.9
500 TO 519						
480 TO 499						
460 TO 479						
440 TO 459		3	3		5.6	5.6
420 TO 439		3	3		5.6	5.6
400 TO 419		8	8		14.7	14.7
380 TO 399	4	13	17	7.4	24.1	31.5
360 TO 379	9	6	15	16.7	11.1	27.8
340 TO 359	2	3	5	3.7	5.6	9.3
320 TO 339	2		2	3.7		3.7
TOTAL	17	37	54	31.5	68.5	100.0

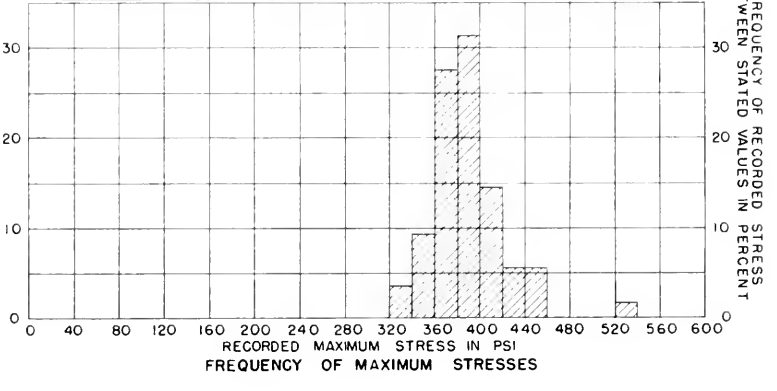
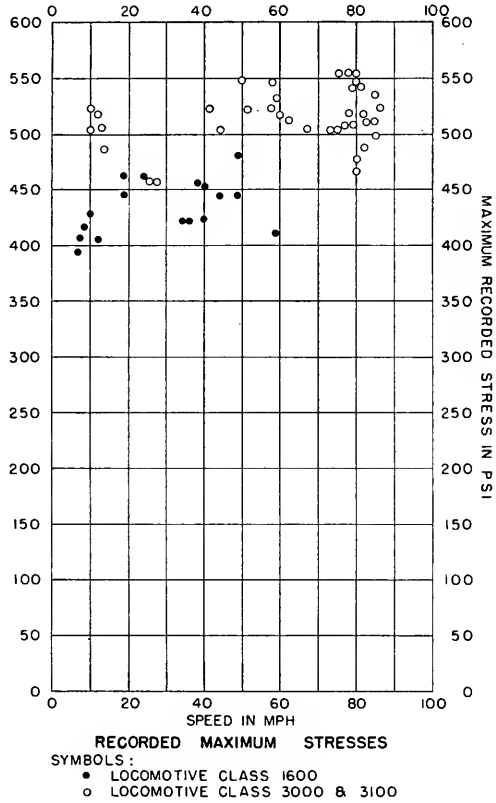


FIG. 27
S. A. L. R. R. TIMBER TRESTLE TEST
FREQUENCY OF MAXIMUM STRESSES
BRIDGE 996



STRESS RANGE DISTRIBUTION BENT 4, GAGE 20						
STRESS RANGE OF RECORDED MAXIMUM STRESS IN PSI	NUMBER OF READINGS FOR EACH STRESS RANGE			PERCENT OF TOTAL READINGS		
	LOCO. CLASS			LOCO. CLASS		
	1600	3000 3100	TOTAL	1600	3000 3100	TOTAL
540 TO 559		8	8		14.8	14.8
520 TO 539		7	7		13.0	13.0
500 TO 519		15	15		27.7	27.7
480 TO 499	1	3	4	1.9	5.5	7.4
460 TO 479	2	2	4	3.7	3.7	7.4
440 TO 459	5	2	7	9.3	3.7	13.0
420 TO 439	4		4	7.4		7.4
400 TO 419	4		4	7.4		7.4
380 TO 399	1		1	1.9		1.9
TOTAL	17	37	54	31.6	68.4	100.0

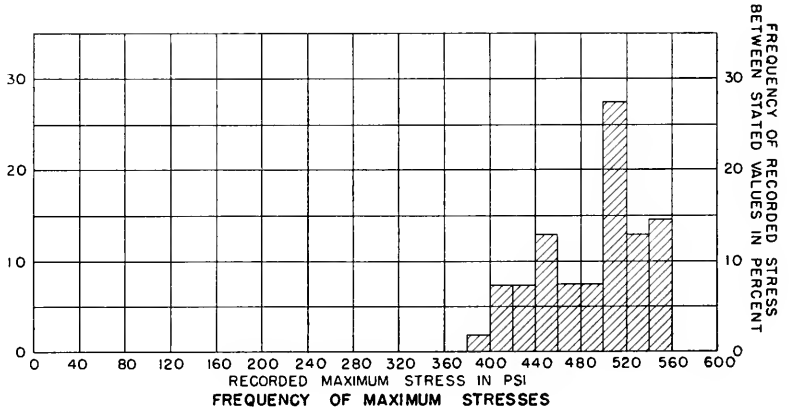
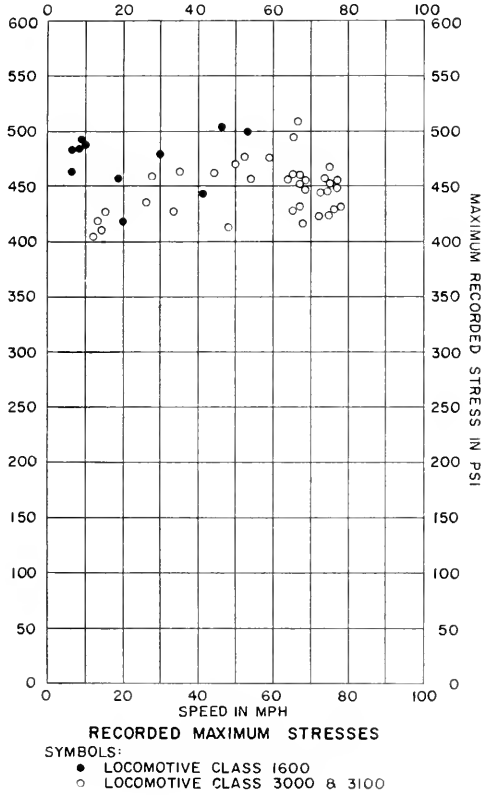


FIG. 28
S.A.L. R.R. TIMBER TRESTLE TEST
FREQUENCY OF MAXIMUM STRESSES
BRIDGE 1009



STRESS RANGE DISTRIBUTION SPAN 12, GAGE 26						
STRESS RANGE OF RECORDED MAXIMUM STRESS IN PSI	NUMBER OF READINGS FOR EACH STRESS RANGE			PER CENT OF TOTAL READINGS		
	LOCO. CLASS		TOTAL	LOCO. CLASS		TOTAL
	1600	3000 3100		1600	3000 3100	
500 TO 519	2	1	3	4.3	2.1	6.4
480 TO 499	4	1	5	8.5	2.1	10.6
460 TO 479	2	8	10	4.3	17.0	21.3
440 TO 459	2	12	14	4.3	25.5	29.8
420 TO 439		9	9		19.2	19.2
400 TO 419	1	5	6	2.1	10.6	12.7
TOTAL	11	36	47	23.5	76.5	100.0

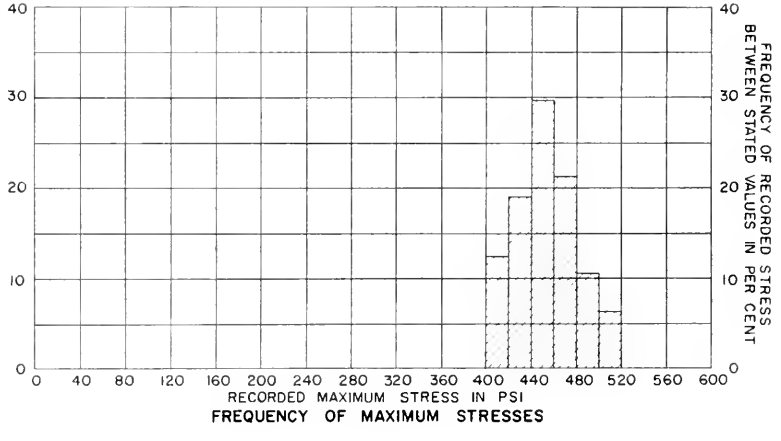
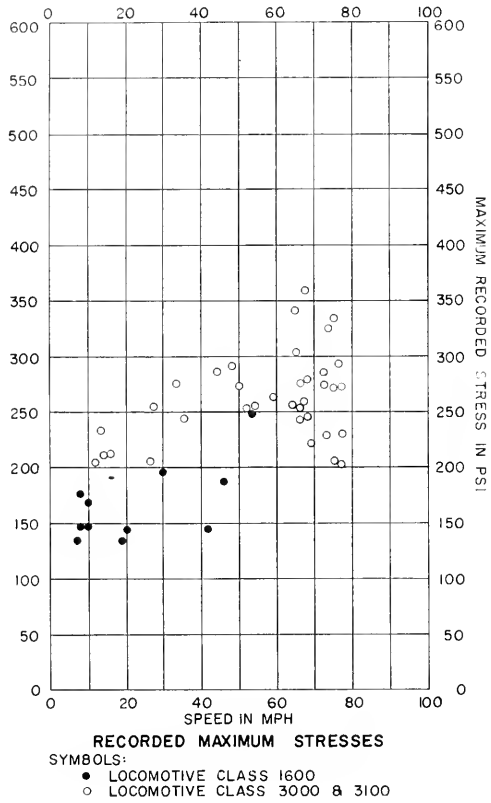


FIG. 29
S.A.L. R.R. TIMBER TRESTLE TEST
FREQUENCY OF MAXIMUM STRESSES
BRIDGE 1009



STRESS RANGE DISTRIBUTION
BENT 13, GAGE 19

STRESS RANGE OF RECORDED MAXIMUM STRESS IN PSI	NUMBER OF READINGS FOR EACH STRESS RANGE			PER CENT OF TOTAL READINGS		
	LOCO. CLASS			LOCO. CLASS		
	1600	3000 3100	TOTAL	1600	3000 3100	TOTAL
340 TO 359		2	2		4.3	4.3
320 TO 339		2	2		4.3	4.3
300 TO 319		1	1		2.1	2.1
280 TO 299		4	4		8.5	8.5
260 TO 279		8	8		17.0	17.0
240 TO 259		9	9		19.0	19.0
220 TO 239	1	4	5	2.1	8.5	10.6
200 TO 219		6	6		12.8	12.8
180 TO 199	2		2	4.3		4.3
160 TO 179	2		2	4.3		4.3
140 TO 159	4		4	8.5		8.5
120 TO 139	2		2	4.3		4.3
TOTAL	11	36	47	23.5	76.5	100.0

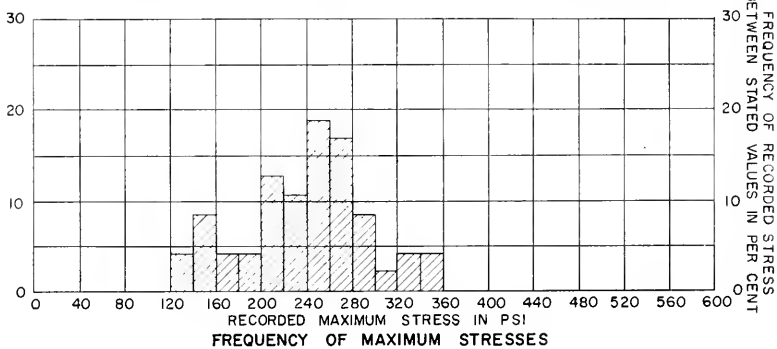


FIG. 30
S.A.L. R.R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESSES IN PILES
BRIDGE 996

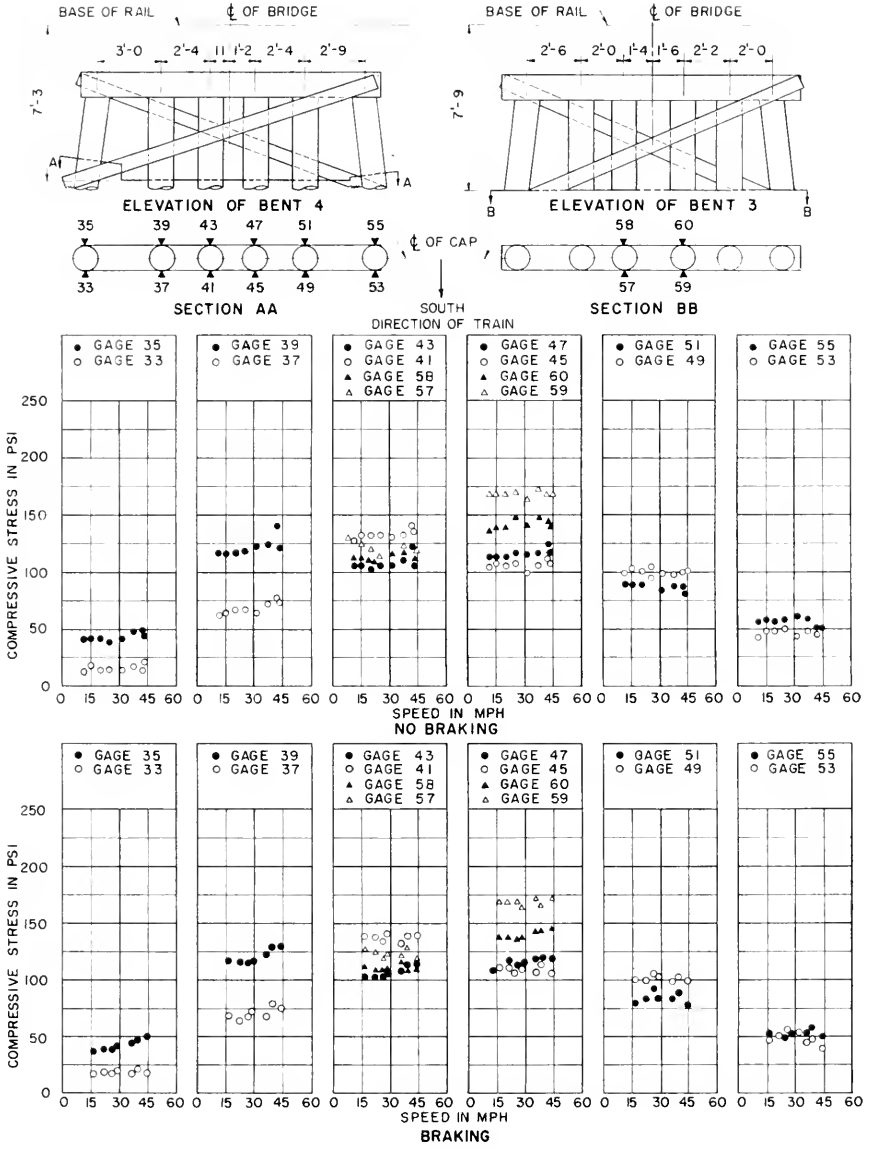


FIG. 31
S. A. L. R. R. TIMBER TRESTLE TEST
MAXIMUM RECORDED STRESSES IN PILES
BRIDGE 1009

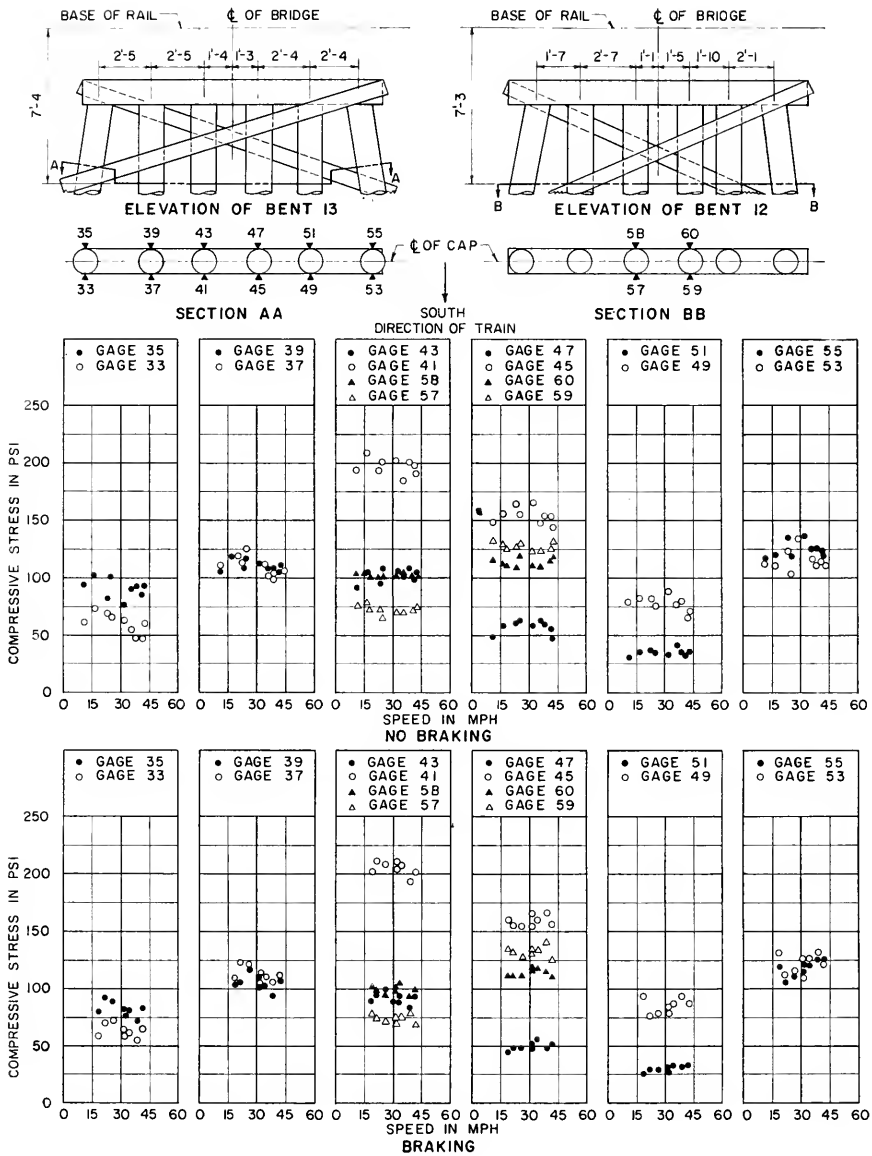
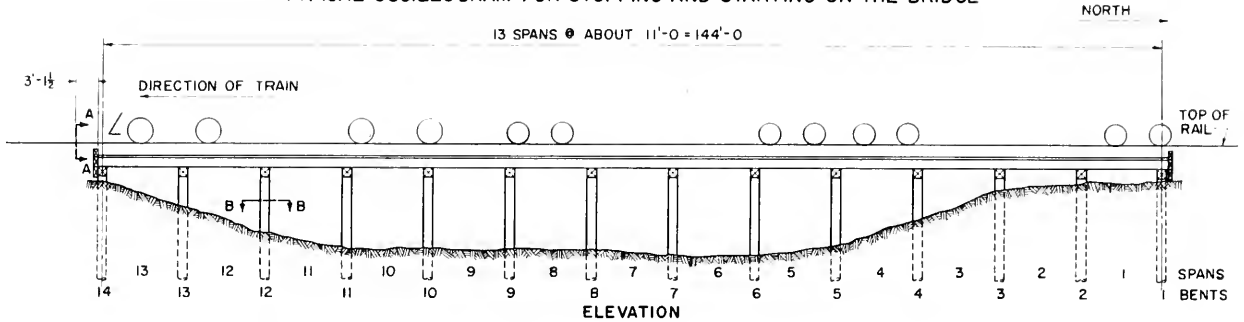
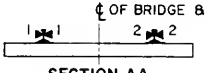


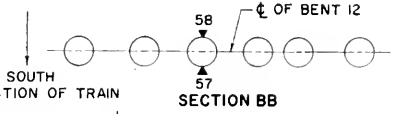
FIG. 32
S. A. L. R. R. TIMBER TRESTLE TEST
TYPICAL OSCILLOGRAM FOR STOPPING AND STARTING ON THE BRIDGE

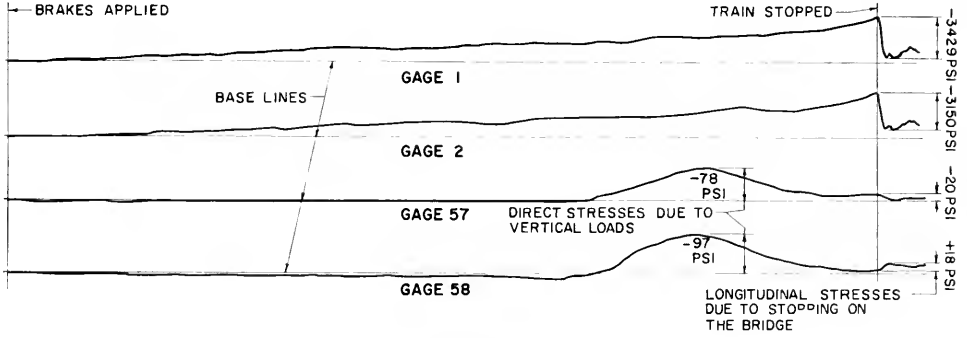


POSITION OF TRAIN WHEN IT STOPPED. AFTER STOPPING, THE TRAIN ACCELERATED FORWARD.

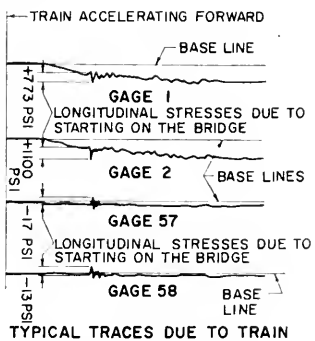


SYMBOLS:
▲ SR 4 STRAIN GAGES





TYPICAL TRACES DUE TO TRAIN STOPPING ON THE BRIDGE



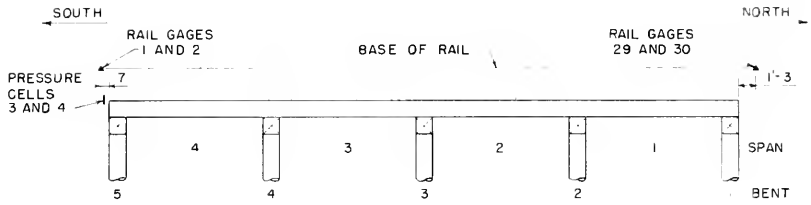
TYPICAL TRACES DUE TO TRAIN STARTING ON THE BRIDGE

FIG 33

S A L R R TIMBER TRESTLE TEST

RECORDED LONGITUDINAL AND DIRECT STRESSES

BRIDGE 996



SEE FIG. 2 FOR LOCATION OF GAGES

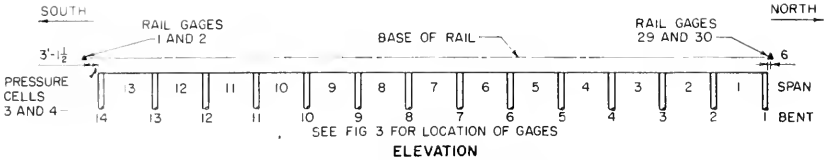
ELEVATION

NOTE: FOR PILE GAGES ON BENTS 4 AND 5, THE TOP NUMBER INDICATES THE RECORDED STRESS VALUE FROM VERTICAL LOADS AND THE BOTTOM NUMBER INDICATES THE RECORDED STRESS VALUE FROM BRAKING TO A STOP ON THE BRIDGE.

RUN NO.	STRESSES FROM VERTICAL LOADS IN PSI AND STRESSES FROM BRAKING TO A STOP ON THE BRIDGE IN PSI																STRESSES FROM BRAKING TO A STOP ON THE BRIDGE IN PSI						
	GAGES ON BENT 4												GAGES ON BENT 3				RAIL GAGES				PRESSURE CELLS		*DIST. FT.
	55	53	51	49	47	45	43	41	39	37	35	33	60	59	58	57	1	2	29	30	3	4	
129	−42 +28	−58 −41	−83 +17	−105 −31	−104 +20	−111 −27	−99 +16	−140 − 35	−108 +20	−72 −31	− 31 +17	− 19 −16	−132 +27	−165 − 16	−107 +20	−130 − 13	− 1555	− 1761	+ 2133	+ 1876	− 1 60	− 0.39	- 13'-8
130	— +19	— −22	— +17	— −19	— +17	— −14	— +16	— − 19	— +17	— −17	— +14	— − 9	−38 − 5	− 66 − 16	− 33 − 6	− 55 − 14	− 1750	− 1690	+ 445	+ 346	− 1 57	− 0.38	+29'-11
131	— +22	— −30	— +14	— −25	— +14	— −19	— +14	— − 27	— +17	— −22	— +17	— −14	−130 − 6	−173 − 25	−105 − 5	−144 − 25	− 2138	− 1988	+ 346	+ 395	− 1 52	− 0 44	+21'-4
132	− 11 +31	− 89 −55	− 64 +17	−124 −49	− 83 +20	−119 −38	− 79 +19	−168 − 52	− 89 +22	− 91 −42	− 19 +20	− 38 −22	−144 +27	−192 + 16	−121 +24	−170 + 11	− 2673	− 2734	+ 1235	+ 1186	− 2 67	− 0 71	+12'-1
133	— +24	— −30	— +16	— −25	— +19	— − 17	— +14	— − 25	— +17	— −22	— +17	— − 13	−121 − 6	−165 − 25	−102 − 9	−127 − 25	− 1993	− 1938	+ 395	+ 445	− 1 72	− 0.44	+22'-11
134	— +19	— −28	— +14	— −22	— +11	— −19	— + 9	— − 25	— +13	— −25	— +11	— − 13	−127 + 6	−173 − 11	−108 0	−144 − 17	− 1847	− 1740	+ 296	+ 395	− 1 62	− 0 41	+19'-5
135	− 20 +27	− 88 −42	− 71 +14	−130 −33	− 89 +17	−133 −27	− 85 +14	−181 − 35	− 91 +17	− 94 −31	− 19 +19	− 36 − 17	−127 +24	−171 + 8	−107 +17	−137 + 6	− 2430	− 2286	+ 988	+ 1186	− 2 59	− 0.79	+ 9'-8
136	− 42 +30	− 60 −25	− 77 +27	−108 − 19	−102 +25	− 75 − 9	− 96 +24	−146 − 17	−107 + 28	− 71 − 19	− 30 +19	− 33 − 11	−126 − 9	−151 − 25	−110 − 6	−160 − 25	− 2041	− 2087	+ 2124	+ 2025	− 1 77	− 0.74	- 4'- 9

* THE MINUS SIGN INDICATES THE DISTANCE THE TRAIN STOPPED SOUTH OF THE RAIL GAGES AT SOUTH END OF BRIDGE AND THE PLUS SIGN INDICATES THE DISTANCE THE TRAIN STOPPED NORTH OF THE RAIL GAGES AT SOUTH END OF BRIDGE.

FIG. 34
S.A.L. R.R. TIMBER TRESTLE TEST
RECORDED LONGITUDINAL AND DIRECT STRESSES
BRIDGE 1009



ELEVATION

NOTE: FOR PILE GAGES ON BENTS 12 AND 13, THE TOP NUMBER INDICATES THE RECORDED STRESS VALUE FROM VERTICAL LOADS AND THE BOTTOM NUMBER INDICATES THE RECORDED STRESS VALUE FROM BRAKING TO A STOP ON THE BRIDGE.

RUN NO.	STRESSES FROM VERTICAL LOADS IN PSI AND STRESSES FROM BRAKING TO A STOP ON THE BRIDGE IN PSI — GAGES ON BENT 13												GAGES ON BENT 12				STRESSES FROM BRAKING TO A STOP ON THE BRIDGE IN PSI — RAIL GAGES				PRESSURE CELLS		[o] DIST. FT.
	55	53	51	49	47	45	43	41	39	37	35	33	60	59	58	57	1	2	29	30	3	4	
STOPPING ON THE BRIDGE																							
244	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−1023	−986	+779	+887	−0.42	−0.53	34'-11½
	+17	−13	+13	−15	+15	−17	+17	−17	+17	−13	+13	−12	+3	−7	+3	−8							
245	—	—	—	—	—	—	—	—	—	—	—	—	−100	−135	−95	−80	−2971	−2909	+1558	+1627	−1.20	−1.50	17'- 1½
	+40	−50	+42	−60	+45	−80	+52	−75	+53	−63	+35	−33	+20	−8	+20	−12							
246	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−763	−740	+536	+682	−0.31	−0.38	40'- 6½
	+12	−10	+10	−10	+12	−10	+10	−10	+12	−10	+10	−7	+3	−5	+5	−3							
247	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−1705	−1528	+1120	+1134	−0.81	−0.98	29'-11½
	+23	−22	+20	−18	+20	−23	+25	−23	+25	−28	+20	−15	0	−13	0	−13							
248	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−1948	−1775	+1510	+1479	−0.94	−1.25	29'- 5½
	+30	−25	+25	−25	+25	−20	+20	−32	+30	−28	+25	−20	0	−18	0	−17							
249	—	—	—	—	—	—	—	—	—	—	—	—	−107	−129	−95	−75	−682	−641	+438	+493	−0.25	−0.29	18'- 7½
	+12	−10	+12	−12	+15	−15	+12	−17	+13	−13	+8	−8	+3	−5	+3	−3							
250	−87	−147	−5	−112	−18	−179	−52	−212	−67	−124	−58	−68	−104	−130	−97	−78	−3429	−3150	——	——	−1.18	−1.54	8'- 8½
	+52	−43	+50	−52	+53	−60	+65	−53	+58	−48	+45	−35	+15	−10	+18	−20							
252	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−584	−592	+536	+444	−0.29	−0.36	130'- 2½
	+12	−12	+10	−12	+10	−13	+13	−13	+12	−10	+10	−8	+3	−3	+3	−3							
253	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−584	−592	——	——	−0.26	−0.36	133'- 0½
	+12	−8	+8	−10	+12	−12	+12	−12	+12	−12	+12	−8	+3	−3	+3	−3							
254	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−882	−784	+682	+592	−0.35	−0.50	126'- 9½
	+17	−13	+12	−15	+15	−15	+17	−15	+15	−13	+12	−12	+3	−5	+3	−5							
255	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−1023	−986	——	——	−0.52	−0.71	108'- 3½
	+20	−13	+13	−15	+15	−20	+20	−18	+18	−17	+15	−13	+5	−5	+5	−5							
TRACTION																							
	STRESSES FROM STARTING ON THE BRIDGE IN PSI																						
244	−12	+10	−8	+8	−10	+10	−13	+13	−12	+8	−8	+8	+17	+12	+10	+5	+584	+592	−731	−740	+0.09	+0.07	34'-11½
245	——	——	——	——	——	——	——	——	——	——	——	——	−28	−28	−33	−22	+633	+493	−584	−641	+0.08	+0.04	17'- 1½
247	−12	+10	−12	+12	−12	+13	−13	+15	−13	+12	−12	+8	+23	+20	+23	+13	+633	+641	−974	−937	+0.16	+0.13	29'-11½
248	−13	+13	−8	+12	−12	+15	−13	+17	−12	+13	−12	+8	+15	+15	+23	+15	+682	+690	−925	−937	+0.16	+0.13	29'- 5½
250	——	——	——	——	——	——	——	——	——	——	——	——	−12	−25	−13	−17	+773	+1100	−789	−838	+0.07	+0.06	8'- 8½

[o] THIS IS THE DISTANCE THE TRAIN STOPPED NORTH OF THE RAIL GAGES AT THE SOUTH END OF THE BRIDGE.

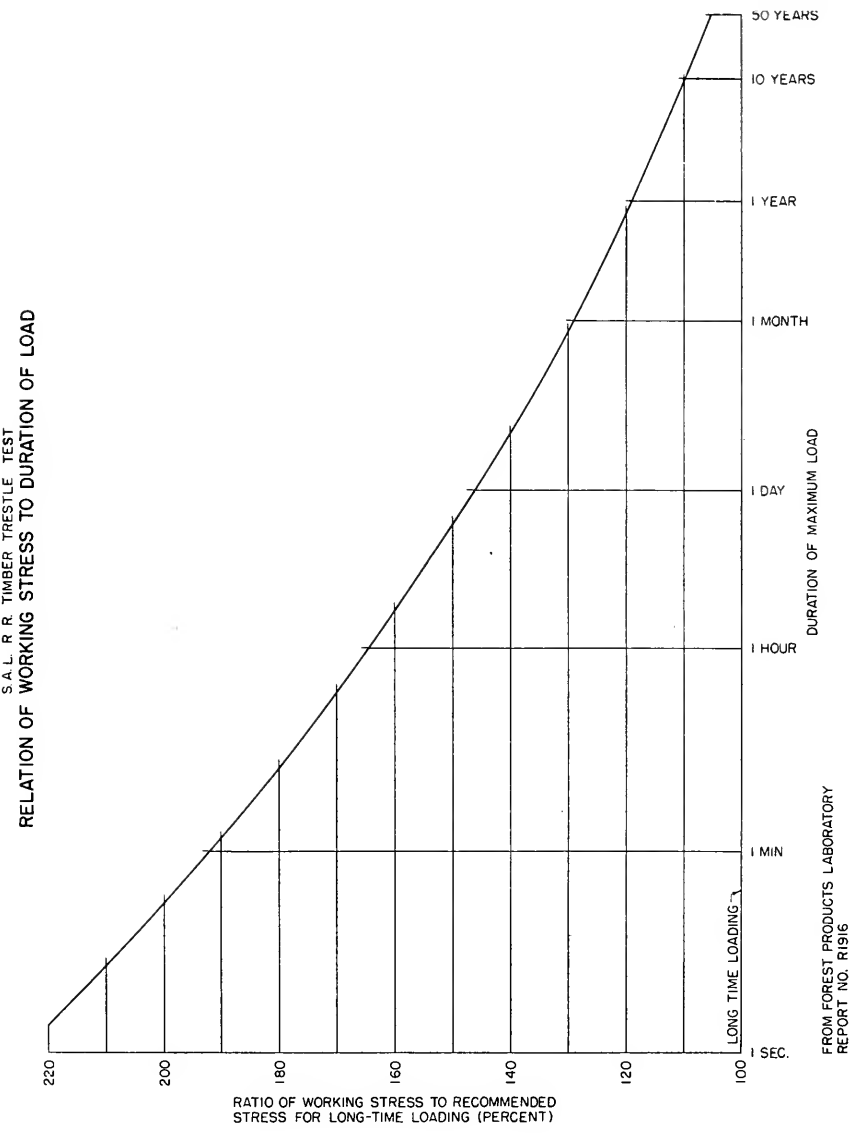
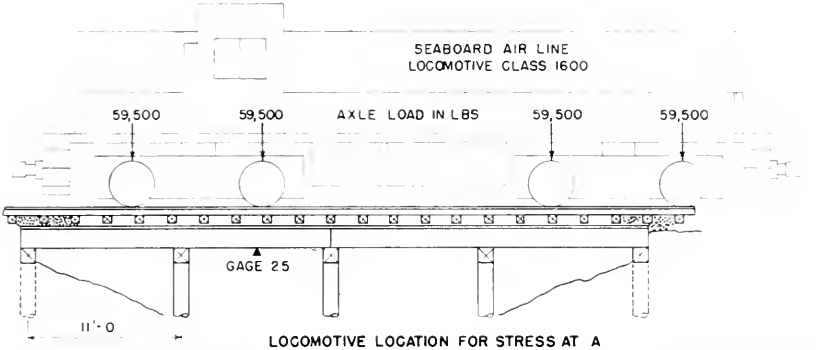
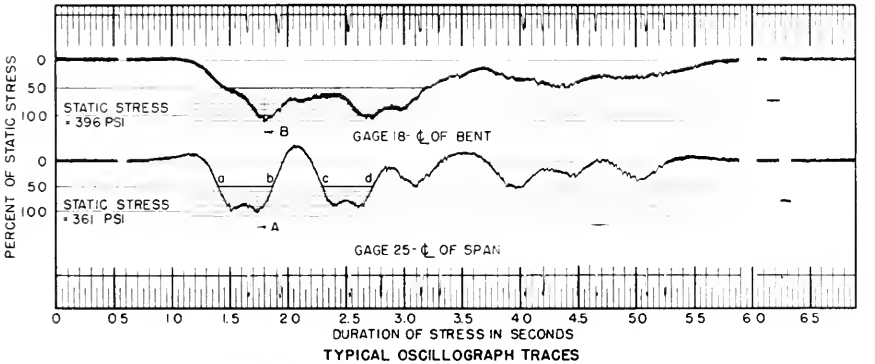


FIG. 35
S.A.L. R.R. TIMBER TRESTLE TEST
RELATION OF WORKING STRESS TO DURATION OF LOAD
50 YEARS
10 YEARS
1 YEAR
1 MONTH
1 DAY
1 HOUR
1 MIN
1 SEC.
LONG TIME LOADING
DURATION OF MAXIMUM LOAD
220
200
180
160
140
120
100
RATIO OF WORKING STRESS TO RECOMMENDED STRESS FOR LONG-TIME LOADING (PERCENT)
FROM FOREST PRODUCTS LABORATORY REPORT NO. R1916

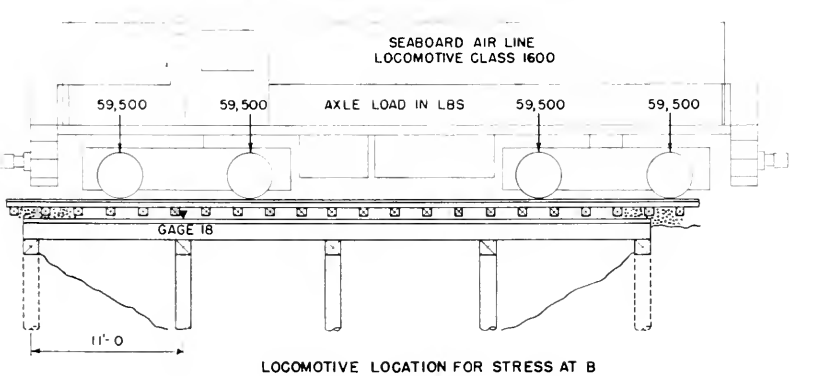
FIG 36
S A L R R TIMBER TRESTLE TEST
TYPICAL OSCILLOGRAM



LOCOMOTIVE LOCATION FOR STRESS AT A



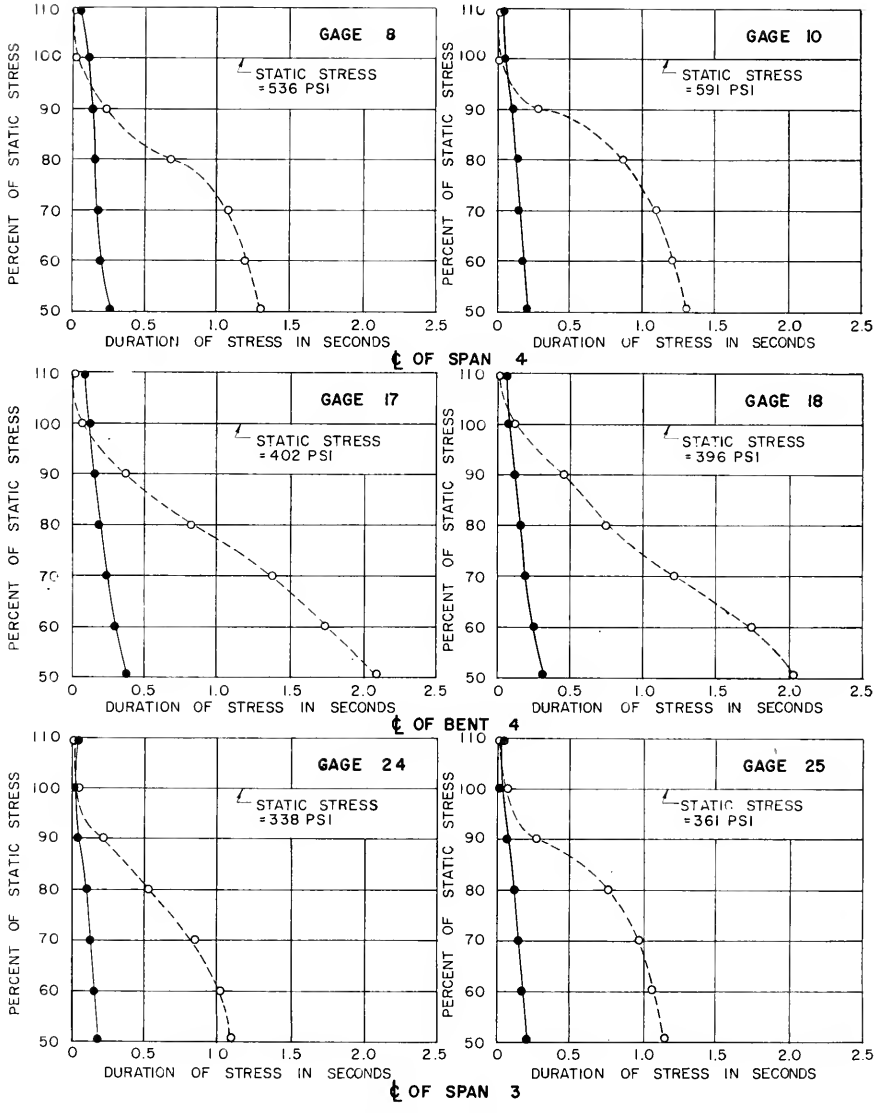
TYPICAL OSCILLOGRAPH TRACES



LOCOMOTIVE LOCATION FOR STRESS AT B

FIG. 37
S. A. L. R R TIMBER TRESTLE TEST
AVERAGE DURATION OF STRESS
BRIDGE 996
LOCOMOTIVE CLASS 1600

SEE FIG 2 FOR LOCATION OF GAGES.



SYMBOLS:
o-----o DURATION OF STRESS PER DIESEL LOCOMOTIVE UNIT.
●——● DURATION OF STRESS PER CAR

FIG. 38
S A L R R TIMBER TRESTLE TEST
AVERAGE DURATION OF STRESS
BRIDGE 996
LOCOMOTIVE CLASS 3000

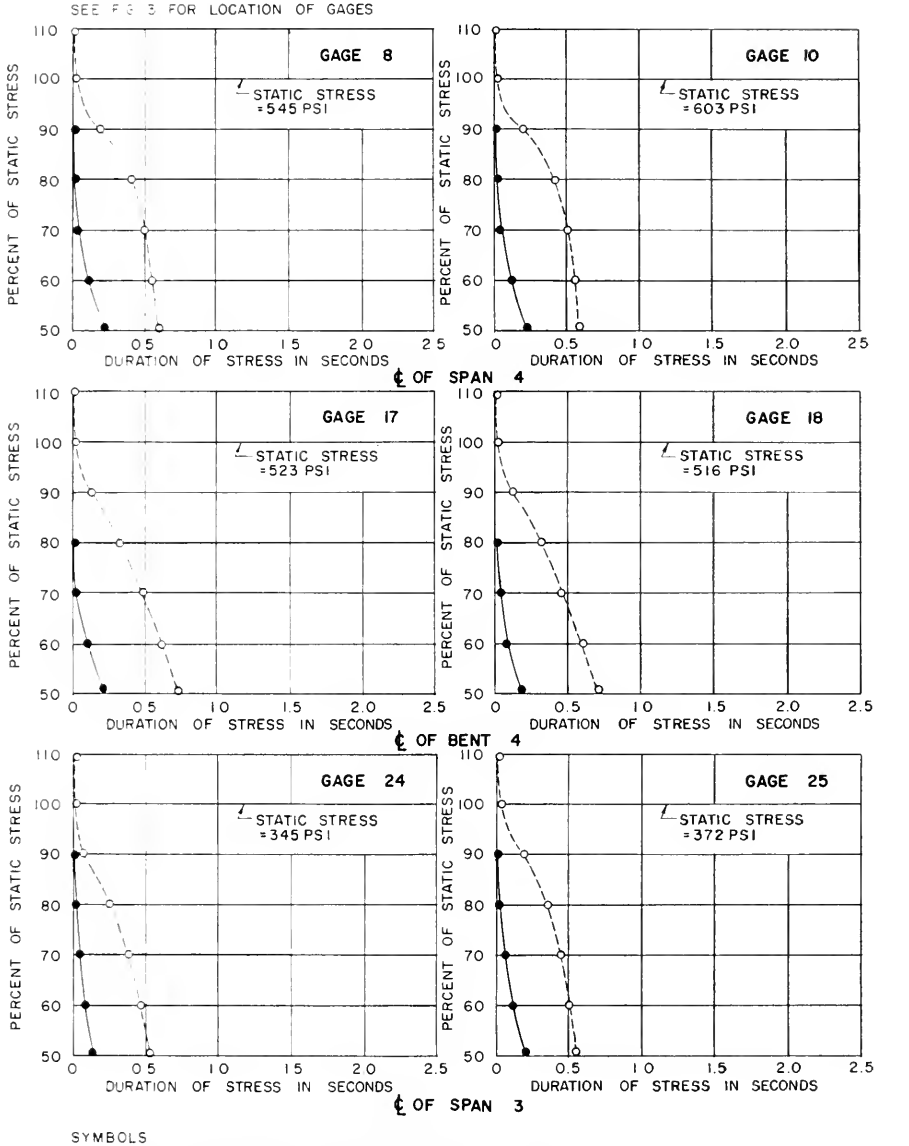


FIG. 39
S. A. L. R. R. TIMBER TRESTLE TEST
AVERAGE DURATION OF STRESS
BRIDGE 1009
LOCOMOTIVE CLASS 1600

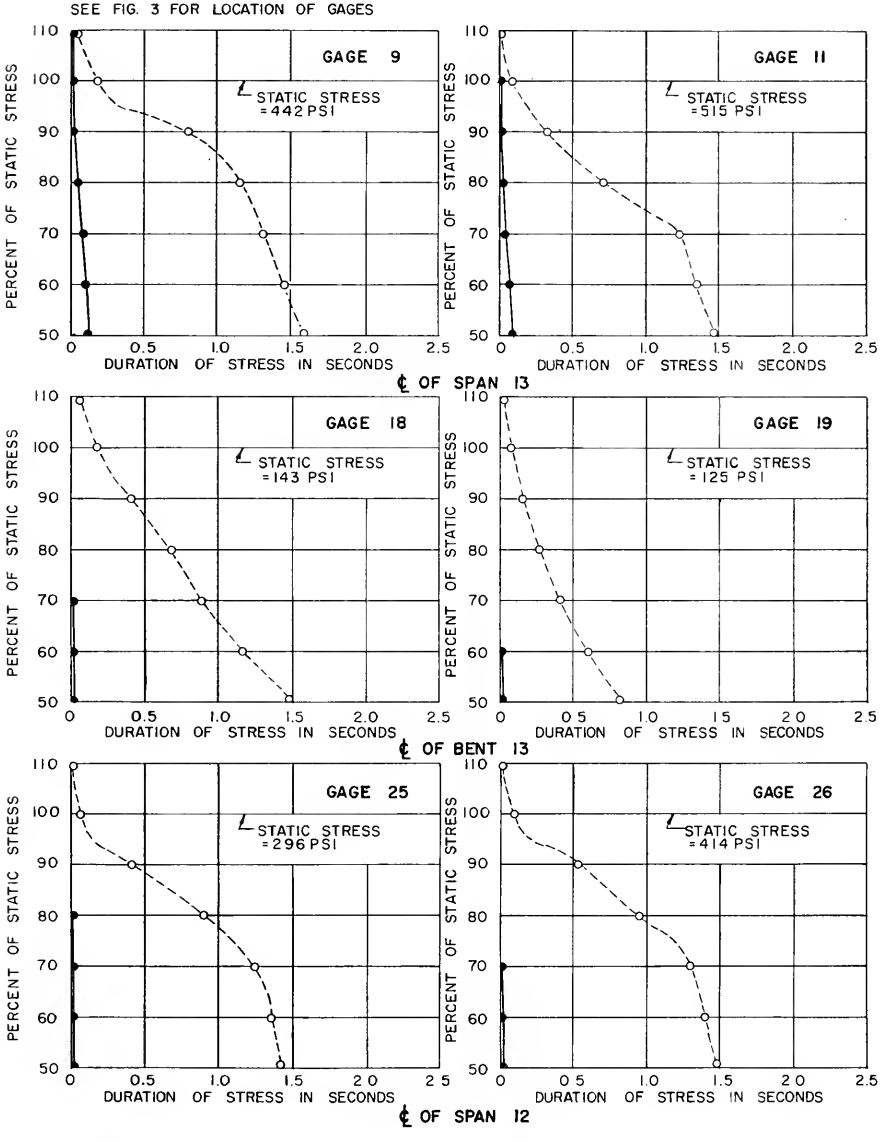


FIG. 40
S. A. L. R. R. TIMBER TRESTLE TEST
AVERAGE DURATION OF STRESS
BRIDGE 1009
LOCOMOTIVE CLASS 3000

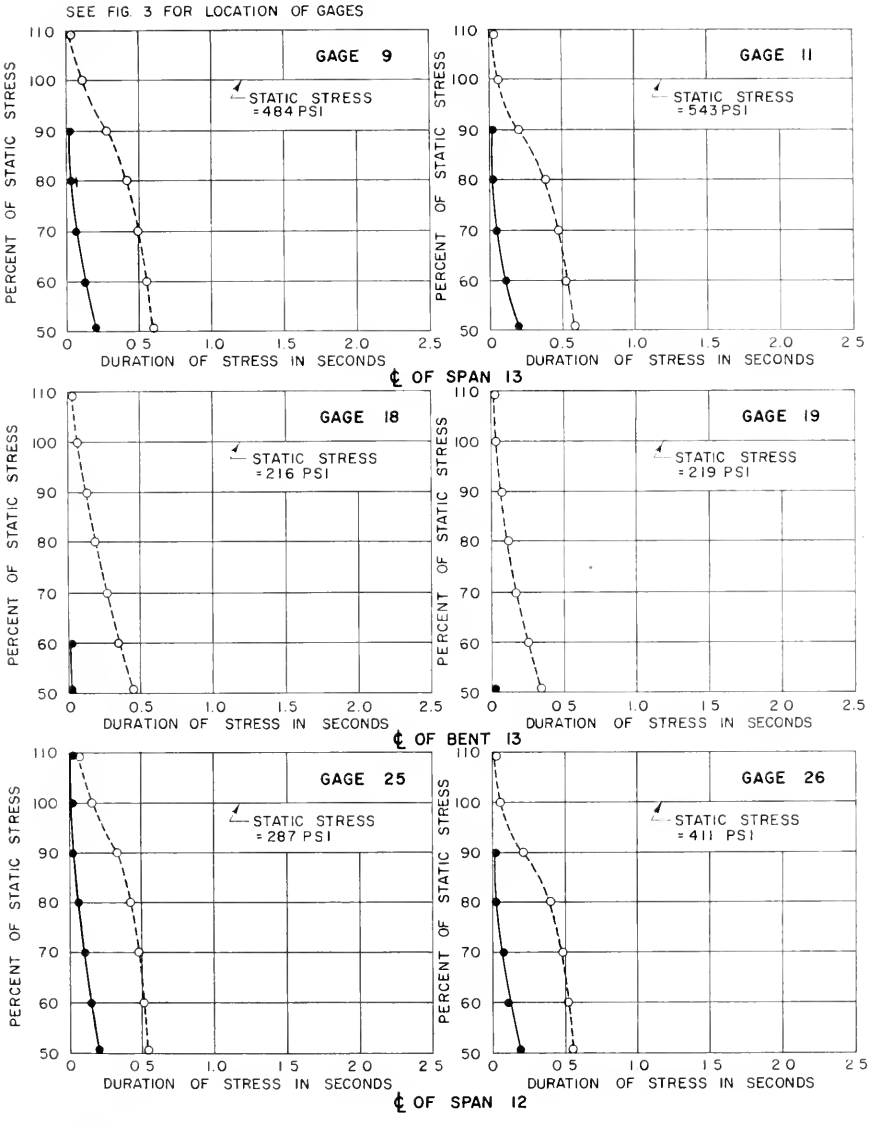
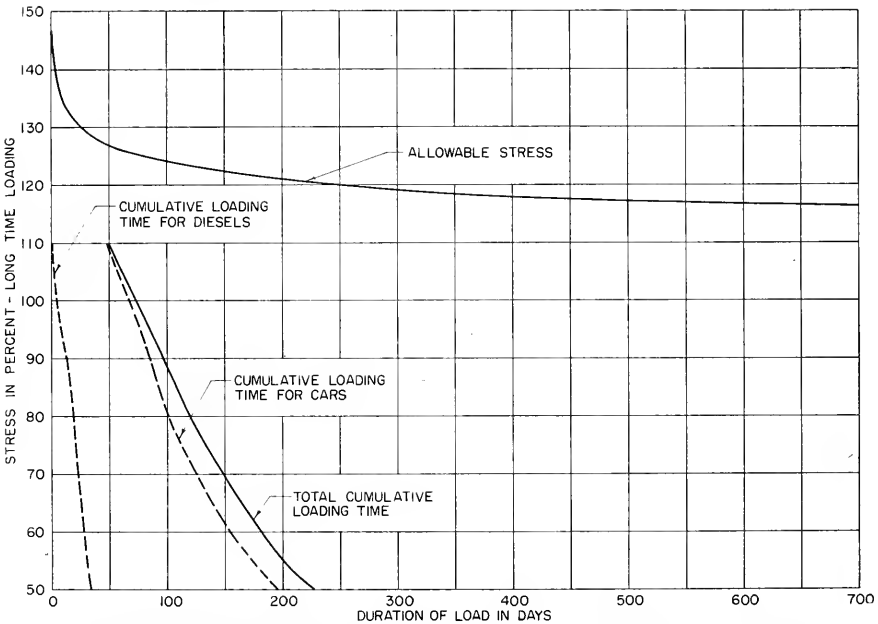
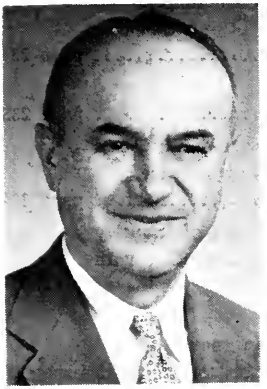


FIG. 41
S.A.L. R.R. TIMBER TRESTLE TEST
CUMULATIVE LOADING TIME WITH RESPECT TO STRESS



NOTE: CUMULATIVE LOADING TIME BASED ON 25 TRAINS PER DAY WITH 3 DIESEL UNITS AND 100 CARS EACH FOR 50 YEARS.

Report of Committee 16—Economics of Railway Location and Operation



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Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress in study, but no report.
2. Effects of degrees of curvature on cost of track maintenance, collaborating with Committees 4 and 5.
   Progress report submitted as information ..... page 210
3. Determination of maintenance of way expenses for various traffic volumes, collaborating with Committee 11.
   Progress report, submitted as information ..... page 216
4. Potential applications of electronic computers to railway engineering and maintenance problems in research, design, inventory, etc., collaborating with Committees 11 and 30, and informally with the Railway Systems and Procedures Association.
   Progress report, submitted as information ..... page 226
5. Methods of reducing time of freight cars between loading and unloading points, collaborating with Car Service Division, AAR, Signal Section, AAR, Operating–Transportation Division, AAR, and American Association of Railroad Superintendents.
   Progress in study, but no report.

6. Economics of improved freight stations and facilities, collaborating with Committees 6 and 14, and with Freight Station Section, AAR.
Progress in study, but no report.

7. Engineering, maintenance and operating benefits to be derived from increased joint use of railway facilities, collaborating with Committees 11, 14, and 20.
Progress report, submitted as information ..... page 231

8. Innovations in railway operations.
Progress report, submitted as information ..... page 233

9. Economics and methods of utilizing railway property, right-of-way, and facilities to develop or increase secondary sources of railway revenue.
Final report, submitted as information ..... page 237

10. Methods of minimizing cost of construction and maintenance of industry tracks to improve the competitive position of railways, collaborating with Committee 11, and with Law Department, AAR.
Progress in study, but no report.

11. Review of developments in new methods and modes of transport.
Progress report, submitted as information ..... page 240

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION AND OPERATION,
R. L. MILNER, *Chairman.*

AREA Bulletin 546, November 1958.

Report of Assignment 2

Effect of Degrees of Curvature on Cost of Track Maintenance

Collaborating with Committees 4 and 5

L. P. Diamond (chairman, subcommittee), J. W. Bolstad, D. E. Brunn, J. E. Inman, C. A. James, A. S. Lang, R. L. Milner, F. B. Peter, E. C. Poole, A. L. Sams, L. E. Ward.

Your committee submits the following report of progress in the gathering and analysis of data to determine the effect of curvature upon the cost of maintaining track.

Previous progress reports on this assignment appear in the Proceedings, Vol. 53, 1952, page 946; Vol. 58, 1957, page 346; and Vol. 59, 1958, page 392. This report presents a study of the influence of track curvature upon costs in ICC Account 218—Ballast. In addition, an analysis is made of the relationship among the primary ICC material accounts and the primary labor account involved in applying these materials to railroad track.

The analyses presented here and in previous progress reports represent individual studies concerning the effects of track curvature on each of Account 212—Ties, Account 214—Rail, Account 216—Other Track Material, Account 218—Ballast, and Account 220—Track Laying and Surfacing. In a future and final report the individual studies will be summarized and coordinated with an over-all analysis of the influence of track curvature on track material and labor cost accounts.

Ballast Account

ICC Account 218 is an accumulation of ballast material cost (excluding betterment costs) for repairs of track. Also included in this account is the cost of work-train service and of unloading the material, as well as certain miscellaneous costs.

On a theoretical basis, considering an idealized track section, and employing the following assumptions:

(a) raise is to be 6 in or less,
(b) ties are about 5 in deep in the ballast,
(c) ballast section is 9 ft 6 in wide across the top (AREA Standard), and
(d) side slope of the ballast section is 2:1,

the percent increase in ballast required to raise superelevated tracks as against tangent track may be expressed as

$$P = \frac{e}{32 + d} \quad \ldots\ldots 1$$

where P = percent increase, curve over tangent
e = superelevation in inches
d = ballast under the ties in inches.

Thus, Equation 1 might be used in a theoretical determination of the influence of curvature upon that portion of an account such as 218 devoted to ballast material costs.

However, recourse to actual volumes of ballast applied to differing types of railroad over many years, like reference to accumulated costs in ICC primary accounts, may involve additional factors not considered in a theoretical approach. Such appears to be the case for the data presented in Table 1, Appendix A, of this report. These data were subjected to a multiple regression analysis using the following equation

$$Y = K\, B^A\, R^C \quad \ldots\ldots 2$$

where Y = accumulated volume of ballast applied, cu yd
K, A, C = equation constants
B = relative track curvature in a mile

$$= \text{sum from } i = 0 \text{ to } N \text{ of } \frac{L_i}{N}\left(\frac{D_i}{2} + 1\right)$$

L_i = length of the i th curve in mile, feet
D_i = degree of the i th curve
N = number of curves in track mile
R = annual traffic rate, MGT/year

A probability analysis of the data in Table 1, Appendix A, indicates that there is no significant relationship between total volume of ballast applied over an 18-year period and either relative track curvature and annual traffic rate or both for each of the ballast types over the 29 miles sampled. Thus, other factors, perhaps such as roadbed stability, ballast subsidence, smoothing, and cribbing, are influential in determining the volume of ballast required in repairs to track. These factors could mask an over-all relationship if they could not be measured or otherwise evaluated in an analysis.

Labor and Material Accounts

A similar situation exists in considering the relationship of accumulated charges between labor and material in ICC Accounts 212 through 220. For example, Account

220 includes the cost of labor expended in applying ties, rails, other track materials and ballast, which material costs are found in Accounts 212, 214, 216 and 218, respectively, plus other costs. These other costs constitute a major portion of Account 220. They are the cost of labor expended in alining, surfacing, gaging and shimming track, in restoring track after accidents, in tightening bolts, etc. Hence, there is no simple relationship between the accumulated costs in the labor and material primary accounts.

Further complications due to differing accounting practices among the railroad companies exist in interpretation of the totals in the primary accounts. For example, in Account 214—Rail, differing salvage values over the years may be applied to determine net costs of rail, sometimes with a distinction between relay rail and scrap, sometimes not. In addition, costs are sometimes expensed to Account 214 which are not in the category of programmed track maintenance work, such as relay rail released for track construction. In Account 218 differing local practices might allocate differing proportions of a given size of ballast raise to capital cost and to operating cost.

Even a moderate breakdown in primary account costs plus limited additional information do not appear sufficient to permit use of primary account totals in determining the effect of curvature on the cost of maintaining track. For example, Table 2, Appendix A, presents data abstracted from a recent study regarding the relationship between the costs in Accounts 218 and 220.

The costs are averaged over a 10-year period. The influence of traffic tonnage and the extent of districts maintained are allowed for by considering costs per million gross-ton-miles per mile. The type of ballast in track is additional information which is useful.

Table 3 of Appendix A presents an analysis of covariance of the data in Table 2. This analysis demonstrates that no significant relationship between Accounts 220 and 218 can be determined based upon the information made available. Fig. 1 of Appendix A is a graphical illustration of the analysis.

Thus, it appears necessary to obtain a more detailed breakdown of the costs in Accounts 212 through 220 in order to determine the effect of curvature on both labor and material costs of maintaining track. It is planned to obtain samples of sufficiently detailed costs from at least two railroads to accomplish the objectives of this study. Analyses of these data will be presented in a future report.

Appendix A

Table 1

Volume of Ballast Applied 1938-1955
And Associated Relative Track Curvature and Annual Traffic Rates

Mile	Total Cu.Yds. Ballast Applied 1938-1955	Feet of Ballasted Track	Relative Track Curvature	Annual Traffic Rate MGT/Yr	
1	1337	5270	1.39	22.0)	
2	2301	5196	1.43	2.5)	
3	2111	5159	1.08	2.5)	
4	2880	5241	3.14	35.0)	
5	1971	5300	1.67	3.5)	
6	4674	4939	2.50	31.5)	
7	5286	5605	2.81	12.4)	Stone
8	4514	5286	2.37	39.5)	Ballast
9	6794	5280	2.26	25.5)	
10	3578	5280	2.26	14.0)	
11	2873	5281	2.84	4.5)	
12	5218	5289	1.40	31.5)	
13	2127	5273	2.04	21.8)	
14	3443	5378	3.38	27.0)	
15	855	5281	2.59	0.5)	
16	3716	5271	5.20	2.5)	
17	1706	5275	1.00	18.0)	
18	6000	5184	2.71	20.0)	
19	4413	5366	3.38	35.0)	
20	3861	5356	2.83	39.0)	
21	4799	5287	1.58	4.0)	Gravel
22	7503	5271	2.60	23.5)	Ballast
23	4932	5306	2.80	16.0)	
24	6104	5260	1.58	10.0)	
25	10011	5138	1.42	12.0)	
26	13604	5281	1.59	12.0)	
27	7770	5219	1.38	43.5)	
28	3048	5283	1.11	14.0)	
29	4356	5173	1.98	10.5)	

Appendix A

Table 2

Comparison of Accounts 218 and 220
Average Cost Per Year in Dollars Per MGTM Per Mile

Division			TYPES OF BALLAST					
			Rock		Gravel		Chat	
			220	218	220	218	220	218
Rock	Gravel	Chat	Y	X	Y	X	Y	X
			$	$	$	$	$	$
1	4	7	107	16	147	29	147	20
2	5	8	126	14	229	43	270	26
3	6	9	142	17	176	24	286	25

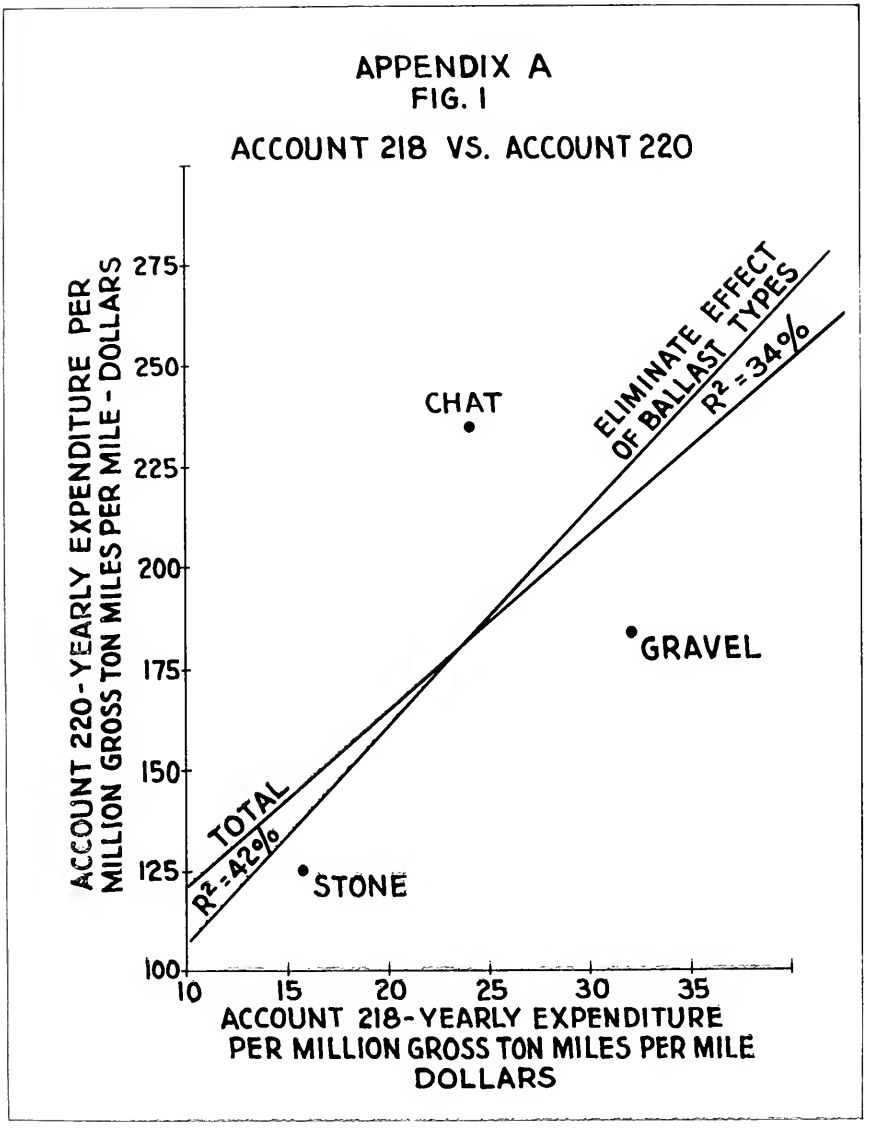
Table 3

A. Analysis of Covariance of Table 2 Data

Source of Variation	Degrees of Freedom	Sums of Squares and Products			Errors of Estimate			
		Sx^2	Sy^2	Sxy	Sum of Squares	Degrees of Freedom	Mean Square	
Total	8	622.89	33608.89	2681.11	22068.57	7		
Among Ballast Types	2	400.22	17967.89	1472.11				
Among Divisions	6	222.67	15641.00	1209.00	9076.66	5	1815	Not
Test of Adjusted Means					12991.91	2	6496	Sig.

B. Analysis of Error Variance

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	
Among Divisions	6	15641	2607	
Reduction due to Regression	1	6564	6564	Not Significant
Error of adjusted means	5	9077	1815	


APPENDIX A
FIG. 1
ACCOUNT 218 VS. ACCOUNT 220
ACCOUNT 220-YEARLY EXPENDITURE PER MILLION GROSS TON MILES PER MILE - DOLLARS
275
250
225
200
175
150
125
100
10
15
20
25
30
35
ACCOUNT 218-YEARLY EXPENDITURE PER MILLION GROSS TON MILES PER MILE DOLLARS
CHAT
GRAVEL
STONE
ELIMINATE EFFECT OF BALLAST TYPES
R² = 34%
TOTAL
R² = 42%

Report on Assignment 3

Determination of Maintenance of Way Expenses for Various Traffic Volumes

Collaborating with Committee 11

J. P. Ray (chairman, subcommittee), B. Chappell, H. B. Christianson, Jr., C. L. Heimbach, H. A. Lind, R. L. Milner, T. C. Nordquist, H. M. Shepard, L. K. Sillcox, C. W. Sooby, C. L. Towle, D. K. Van Ingen, Ferdinand Wascoe.

Your committee submits the following report of progress in the gathering of information pertaining to the study of variable and constant maintenance of way and structures expenses. Comment and criticism of the method herein outlined are invited.

The portion of maintenance of way and structures expenses affected by use, or variable with traffic, has been a controversial and much discussed subject. This committee was given the task of developing a formula which would allow measurement of the maintenance of way and structures expense affected by use. A number of drafts were submitted to the committee members, resulting in considerable discussion and correspondence. A progress report was made at the March 1956 meeting of Committee 16 and at the June 1956 meeting, culminating in publishing the outline of a proposed method of determining variable and constant maintenance of way and structures expense as information in Proceedings of the Fifty-Sixth Annual Convention of the American Railway Engineering Association, Vol. 58, 1957, in anticipation of obtaining assistance in comment and criticism from other sources. This report reflects modifications and revisions resulting from replies to the invitation for comments and criticism on the preceding report.

Extensive changes in maintenance technology occasioned by the development of mechanical equipment and revised maintenance standards and practices preclude the possibility of expressing in a single comprehensive formula the relationship between maintenance of way and structures expenses and traffic volume.

The approach or method developed has been designated as the "experience" formula rather than a theoretical formula in that it measures fluctuations in maintenance expense with the fluctuations in traffic volume. Because of changes in the technology of maintenance it is important that in using this method the base or experience period be chosen so that in estimating past "normal" maintenance or in predicting future maintenance, constantly changing technology will not cause significant variance of the estimated normal expense from the actual expense level.

In arriving at its conclusions, the committee had before it much data and many computations. All cannot be shown here but they can be mentioned. Only those methods considered by the committee as most practical are shown both mathematically and graphically.

A. SIMPLE OR STRAIGHT LINE CORRELATION

1. Many calculations were made using different years of the same railroad, adjusting costs to a common index or cost level. (Example Chart A)

2. Calculations were made using the different divisions of the same railroad for a number of years. (Example Chart B)

3. Calculations were made using 26 of the larger Class I railroads for different individual years. (Example Chart C).

Computations were made on a number of bases, using the straight-line formula

(Text continued on page 220)

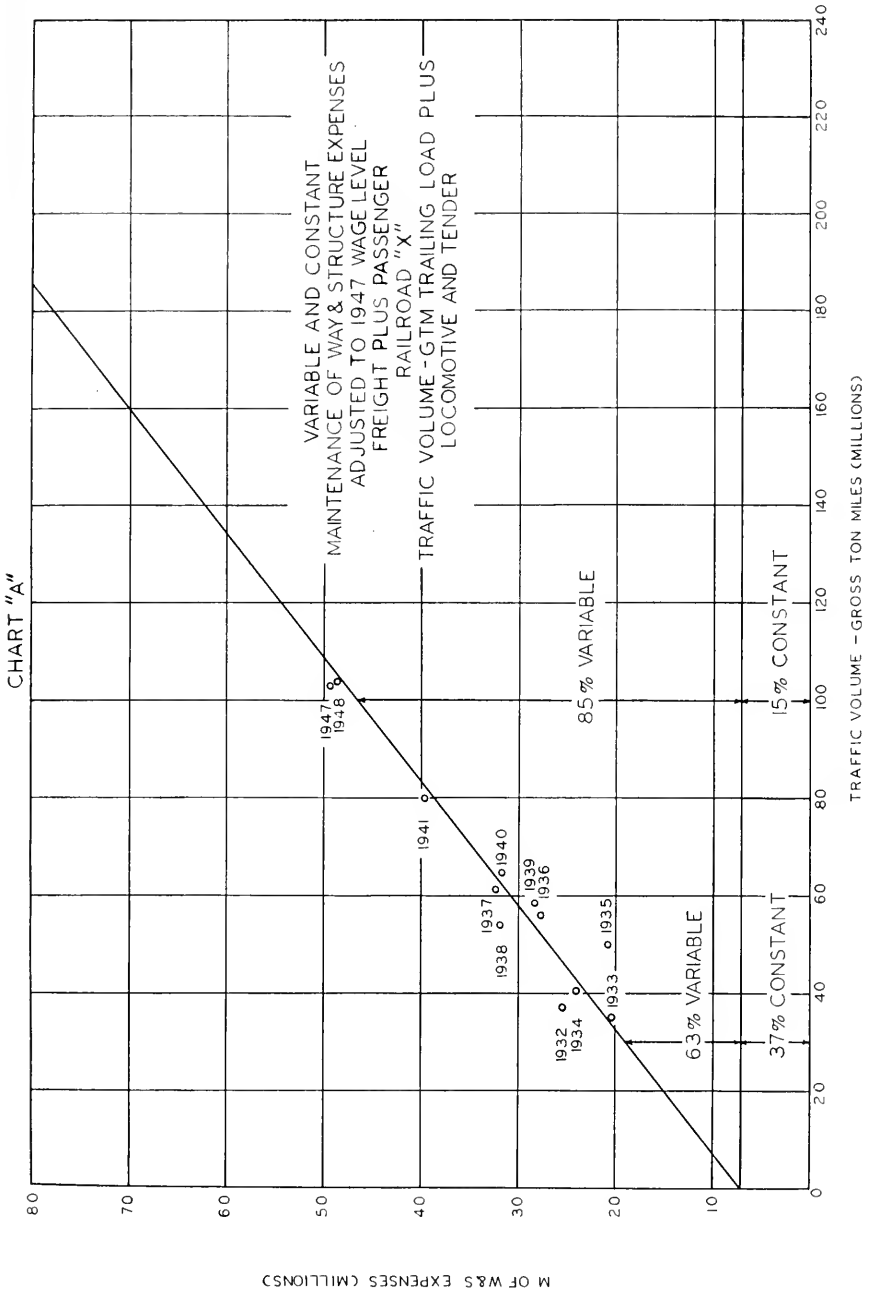
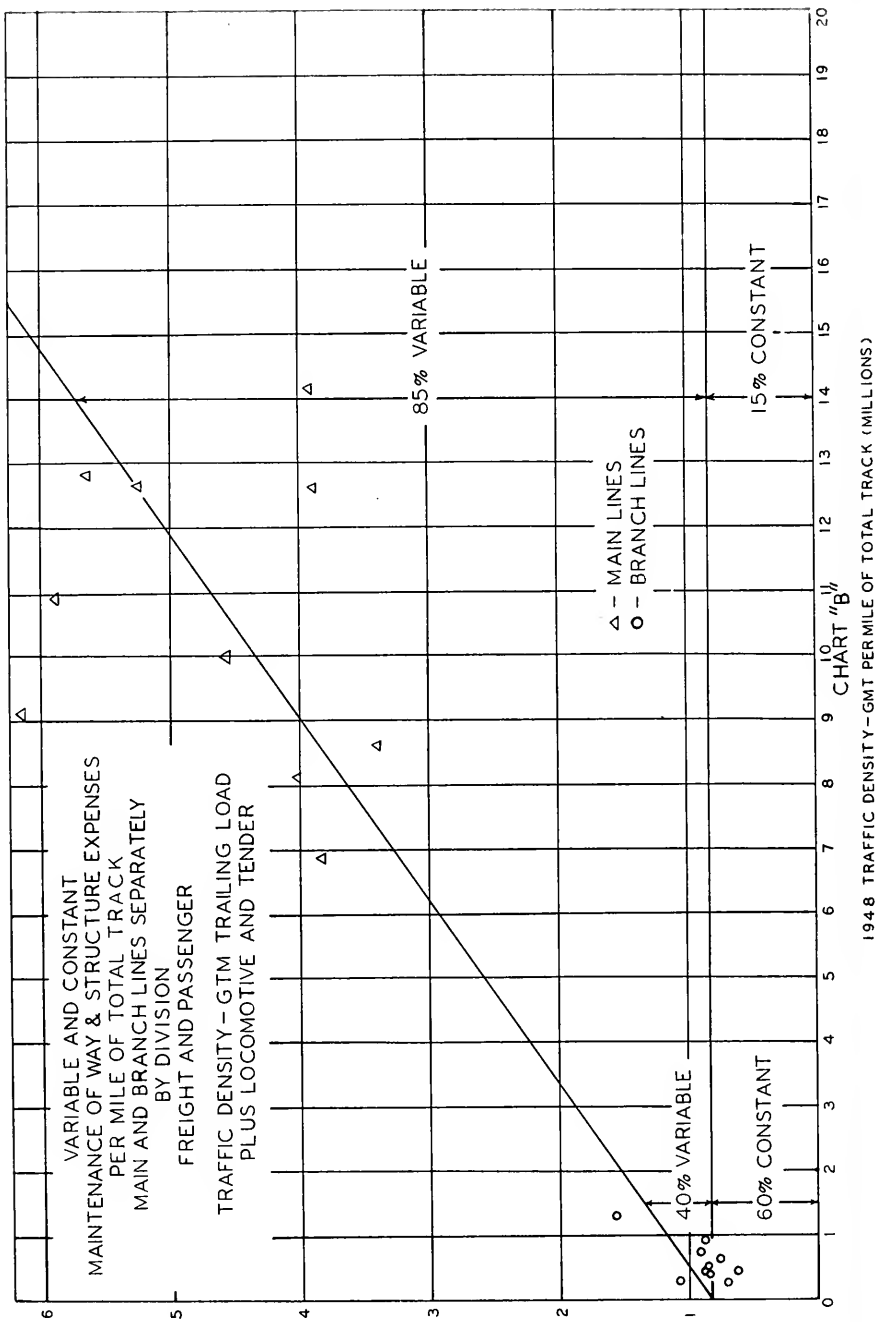


CHART "A"
VARIABLE AND CONSTANT
MAINTENANCE OF WAY & STRUCTURE EXPENSES
ADJUSTED TO 1947 WAGE LEVEL
FREIGHT PLUS PASSENGER
RAILROAD "X"
TRAFFIC VOLUME - GTM TRAILING LOAD PLUS
LOCOMOTIVE AND TENDER
1947
1948
1941
1940
1939
1936
1937
1938
1935
1933
1932
1934
85% VARIABLE
15% CONSTANT
63% VARIABLE
37% CONSTANT
M OF W & S EXPENSES (MILLIONS)
TRAFFIC VOLUME - GROSS TON MILES (MILLIONS)
0
20
40
60
80
100
120
140
160
180
200
220
240
10
20
30
40
50
60
70
80


VARIABLE AND CONSTANT
MAINTENANCE OF WAY & STRUCTURE EXPENSES
PER MILE OF TOTAL TRACK
MAIN AND BRANCH LINES SEPARATELY
BY DIVISION
FREIGHT AND PASSENGER
TRAFFIC DENSITY - GTM TRAILING LOAD
PLUS LOCOMOTIVE AND TENDER
85% VARIABLE
15% CONSTANT
40% VARIABLE
60% CONSTANT
Δ - MAIN LINES
O - BRANCH LINES
CHART "B"
1948 M OF W & S EXPENSES - PER MILE OF TOTAL TRACK (THOUSANDS)
1948 TRAFFIC DENSITY - GMT PER MILE OF TOTAL TRACK (MILLIONS)

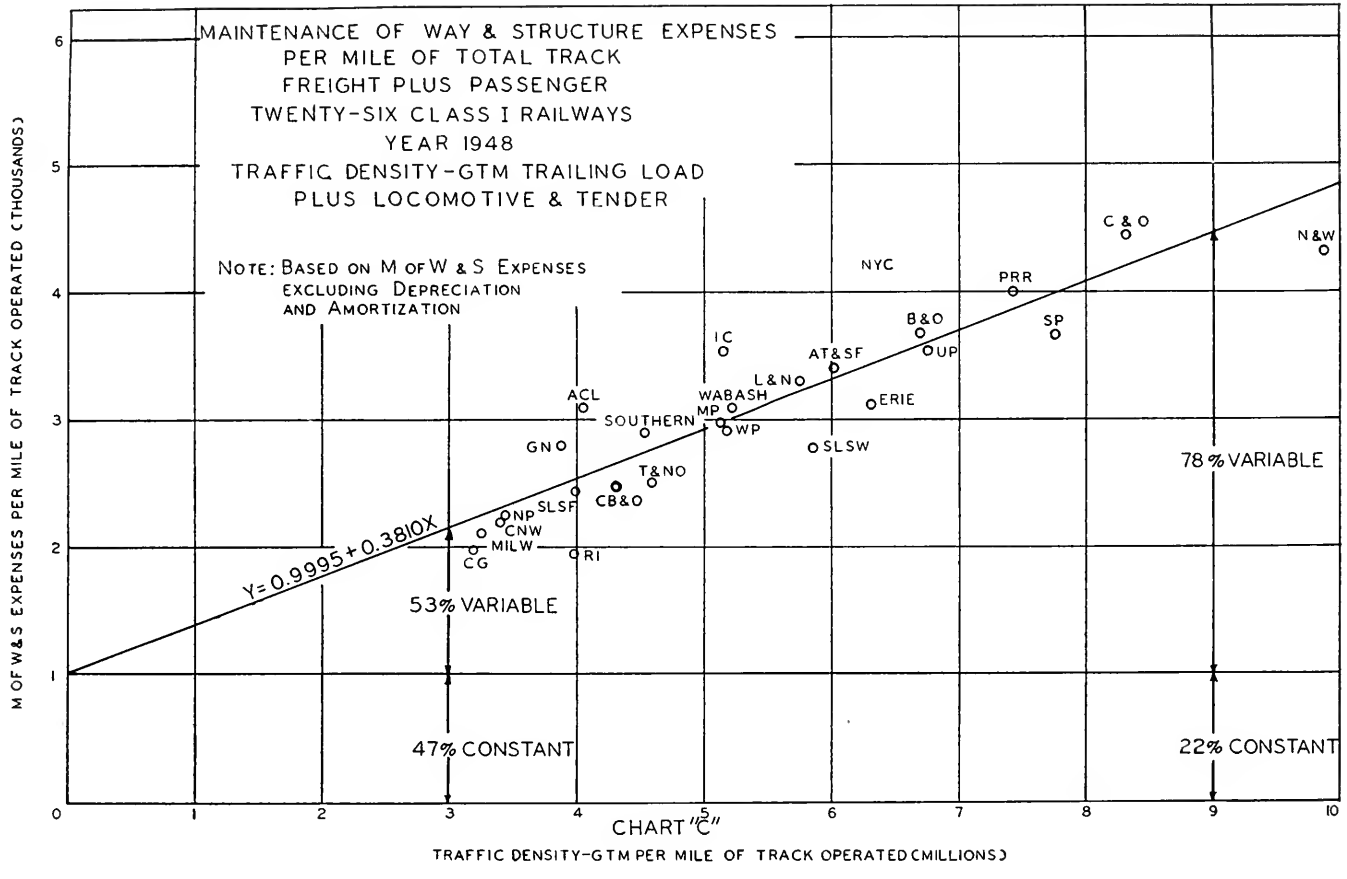

MAINTENANCE OF WAY & STRUCTURE EXPENSES
PER MILE OF TOTAL TRACK
FREIGHT PLUS PASSENGER
TWENTY-SIX CLASS I RAILWAYS
YEAR 1948
TRAFFIC DENSITY-GTM TRAILING LOAD
PLUS LOCOMOTIVE & TENDER
NOTE: BASED ON M OF W & S EXPENSES
EXCLUDING DEPRECIATION
AND AMORTIZATION
Y=0.9995+0.3810X
53% VARIABLE
47% CONSTANT
78% VARIABLE
22% CONSTANT
ACL
SOUTHERN
GNO
NP
SLSF
CNW
MILW
CG
CB&O
RI
T&NO
IC
WABASH
MP
WP
L&NO
AT&SF
SLSW
NYC
ERIE
PRR
B&O
UP
SP
C&O
N&W
M OF W&S EXPENSES PER MILE OF TRACK OPERATED (THOUSANDS)
TRAFFIC DENSITY-GTM PER MILE OF TRACK OPERATED (MILLIONS)
0
1
2
3
4
5
6
7
8
9
10

CHART "C"

($y = a + bx$) to measure the changes in cost with the changes in traffic volume, wherein:

y = Maintenance per mile of track, excluding depreciation and amortization.
x = Traffic density in total gross-ton-miles per mile of track, freight and passenger.
a = A constant to be determined, or the maintenance cost if no traffic were handled.
b = The rate of change in maintenance cost with changes in traffic density.

It was found for the periods studied that calculations using method 3 above gave the most reliable results. In applying method 3 the calculations using the following were made:

(a) The expenses (excluding depreciation and amortization) per mile of track and gross-ton-miles per mile of track of each railroad separately, not weighted as to size.
(b) The expenses (excluding depreciation and amortization) per mile of track and gross-ton-miles per mile of track of each railroad separately, giving weight to each as to size, using gross-ton-miles as the measure for weighting.
(c) The expenses (excluding depreciation and amortization) per mile of track and gross-ton-miles per mile of track of each railroad separately, giving weight to each as to size, using miles of track as the measure of weighting.

The results of the calculations for methods 3 (a), 3 (b) and 3 (c) for each individual year 1954 to 1956, incl., and the 3-year average indexed to the 1957 cost level, for 26 Class I railroads, are shown in the table below. It is believed that method 3 (c) is the most valid method.

Year	*Not Weighted* (a)	*Weighted on Gross-Ton Miles* (b)	*Weighted on Miles of Track* (c)
1954	$y = \$1.1368 + 0.4289x$	$y = \$1.3612 + 0.3716x$	$y = \$1.1853 + 0.4055x$
1955	$y = 1.2532 + 0.3941x$	$y = 1.2403 + 0.3926x$	$y = 1.1424 + 0.4098x$
1956	$y = 1.0636 + 0.4374x$	$y = 1.1172 + 0.4182x$	$y = 1.0788 + 0.4250x$
3-Year Average Indexed to Year 1957	$y = \$1.3190 + 0.4800x$	$y = \$1.4229 + 0.4496x$	$y = \$1.3009 + 0.4723x$

The indices used for combining the 3 individual years to a 3-year average indexed to year 1957 are those developed and currently maintained by a major Class I railroad and check closely indexing data used by the AAR. Index factors are:

1954	120.10
1955	116.27
1956	106.69
1957	100.00

The percent variable and constant can be determined from the average without further adjustment.

$$\text{Percent variable} = \frac{bx}{y} \times 100$$

wherein x = gross-ton-miles (millions) per mile of track

B. MULTIPLE CORRELATION

A number of calculations were made using multiple correlation wherein three or more variables were used. In some of these computations a separation was made

between the effects of passenger gross-ton-miles on expense and freight gross-ton-miles on expense. The results were somewhat erratic, although indicating a higher cost for passenger gross-ton-miles than for freight gross-ton-miles. It is possible, especially with modern electronic data processing equipment, to deal with many independent variables through use of multiple correlation techniques. If more detail is necessary, adequate data are available on significant independent variables, and the results will justify more complicated analysis; it is believed that multiple correlation should be used where more than one independent variable is used.

Multiple correlation calculations were made from the formula:

$$x_1 = a + b_{12.3}\, x_2 + b_{13.2}\, x_3$$

wherein x_1 is the dependent or estimated variable replacing y, and
x_2 and x_3 are independent variables, ie:

x_1 = total maintenance of way and structures expense (excluding depreciation and amortization)

x_2 = miles of total track in thousands

x_3 = gross-ton-miles in millions

$b_{12.3}$ = the change in dependent variable x_1 with a given change in variable x_2

$b_{13.2}$ = the change in dependent variable x_1 with a given change in variable x_3

The results of multiple correlation for each individual year 1954 to 1956, incl., and the 3-year average indexed to 1957 cost level for the same 26 Class I railroads used in methods 3 (a), 3 (b) and 3 (c) are to be found in the table below:

Year								
1954	$1,483,420 + $1.074 ×	Miles of	Total	Track	(000) +	$0.400 ×	Gross-Ton-Miles	(000,000)
1955	$1,313,310 + $1.011	"	"	"	+ 0.412	"	"	"
1956	$1,726,910 + $1.189	"	"	"	+ 0.377	"	"	"
3-year average indexed to year 1957:	$1,717,004 + $1.245	"	"	"	+ 0.426	"	"	"

C. COMPARISON OF TEST COMPUTATIONS

The results of the computations for railroads with theoretical 5 million gross-ton-miles per mile of track and 10 million gross-ton-miles per mile of track are shown below:

Gross-Ton-Miles per Mile of Track	*Simple Correlation*			*Multiple Correlation*
	Not Weighted	*Weighted on Gross-Ton-miles*	*Weighted on Miles of Track*	
(*a*)	(*b*)	(*c*)	(*d*)	(*e*)
5 Million:				
Constant	$1,319	$1,423	$1,301	$1,245
Variable	2,400	2,248	2,362	2,270
Total	$3,719	$3,671	$3,663	$3,515
Percent Variable	64.5	61.2	64.5	64.6
10 Million:				
Constant	$1,319	$1,423	$1,301	$1,245
Variable	4,800	4,496	4,723	4,540
Total	$6,119	$5,919	$6,024	$5,785
Percent Variable	78.4	76.0	78.4	78.5

D. COMPARISON OF ESTIMATED MAINTENANCE COSTS WITH ACTUAL RECORDS—YEAR 1957 CONSTANT DOLLARS—FIVE CLASS I RAILWAY SYSTEMS FOR YEARS 1954 TO 1956 INC.

Using the weighted-on-miles-of-track basis, the computations applied to five large railroad systems distributed throughout the country over a series of years compared with the actual results, and the difference, are shown in the following table:

Year	*GTM (Millions)*	*Miles of Track*	*GTM (Millions) per Mile of Track*	*Percent Variable 0.4723d 0.4723d +1.3009*	*Estimated Dollars* Adjusted to 1957*	*Actual Dollars Adjusted to 1957*	*Difference*	*Percent Difference*
(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)	(*i*)
1954	469,904	86,143	5.455	66.4	$302,822,000	$ 338,401,000	----------	--------
1955	512,497	85,327	6.006	68.6	324,039,000	353,044,000	----------	--------
1956	516,206	84,855	6.083	68.8	326,116,000	327,574,000	----------	--------
Total	----------	--------	----------	--------	$952,977,000	$1,019,019,000	$66,042,000	—6.48
1957	496,307	84,316	5.886	68.1	$318,959,976	$ 318,959,976	----------	--------

Total $318,959,976
Variable $217,211,744
Constant $101,748,232

*Estimated dollars = 1957 constant dollars ($105,575,752) $\times \frac{1}{1 \text{ minus } \% \text{ variable}}$

E. COMPARISON OF ESTIMATED MAINTENANCE COSTS AND ACTUAL RECORDS FOR YEAR 1957—FIVE CLASS I RAILWAY SYSTEMS**

Assuming normal maintenance and base period of years covering a full economic cycle which adequately reflects state of maintenance technology, it is possible to use equation 3 (c) to predict closely what maintenance expenses for a given year will be or should be. The following calculation illustrates this point:

GTM (Millions) = 496,307 Miles of Track = 84,316 GTM (millions) per Mile of Track = 5.886

Estimating equation — $y = 1.3009 + 0.4723x$
Estimated Maintenance = 84,316 $(1.3009 + 0.4723 \times 5.886)$
= $344,081,606
Actual Maintenance = 318,959,976
Percent Difference = 7.88

Any resultant difference between estimated "normal" and actual maintenance expense should be evaluated for causative reasons. The above example might indicate under-maintenance and/or more advanced technology. Where actual maintenance exceeds estimated "normal" maintenance expense, correction of deferred maintenance practices or more severe than average physical characteristics might be indicated.

F. COMMENT ON USE OF EXPERIENCE METHOD OF DETERMINING NORMAL MAINTENANCE EXPENSE

This report is primarily for the purpose of outlining an approach to the determination of changes in maintenance expenses which can be expected for given changes in traffic volume. It is not an attempt to derive a never-changing universal formula. The

** In actual application only one railroad would ordinarily be used.

value of this approach to the user depends entirely on the understanding and wisdom employed in its application. False conclusions can be derived if the method is incorrectly or inappropriately applied.

Maintenance is undergoing continuing technological change; therefore, the base period chosen should reflect at least one full economic cycle and be representative of maintenance practices of the year or periods being tested. Since the method attempts only to measure the effect of traffic volume, a single railroad with significantly different operating conditions should use judgment in applying the experience of the average of 26 roads to his unique conditions. It is suggested that the individual road's difference from the average is reasonably constant; therefore, a simple correction factor could be obtained by testing its actual experience against the results of the average of the 26 railroads for a number of years.

SAMPLE OF CORRELATION

Basic Statistics

Railroad	Total GTM (Thous)	Expenses Excluding Depreciation	Miles of track Operated	Per Mile of Track GTM (Millions)	Per Mile of Track Expenses (Thous)
(a)	(b)	(c)	(d)	(b) ÷ (d)	(c) ÷ (d)
A	25,476	$ 16,240	13,965	1.824	$ 1.163
B	57,914	43,302	14,010	4.134	3.091
C	101,836	66,432	13,567	7.506	4.897
D	130,113	89,324	21,848	5.955	4.088
E	158,436	114,010	23,432	6.762	4.866
Total	473,775	329,308	86,822	26.181	$ 18.105

Simple Correlation:

Railroad	Per Mile of Track GTM (Millions) x	Per Mile of Track Expenses (Thousands) y	xy	x^2
A	1.824	$ 1.163	2.121	3.327
B	4.134	3.091	12.778	17.090
C	7.506	4.897	36.757	56.340
D	5.955	4.088	24.344	35.462
E	6.762	4.866	32.904	45.725
Total	26.181	$ 18.105	108.904	157.944

Normal Equations:-

$\Sigma y = Na + b\Sigma x$

$\Sigma xy = a\Sigma x + b\Sigma x^2$

(1) $18.105 = 5a + 26.181b$ $(26.181 \div 5 = 5.2362)$

(2) $108.904 = 26.181a + 157.944b$

(1') $94.801 = 26.181a + 137.039b$ (1')=(1)x5.2362

$14.103 = 20.355b$

$b = 0.67623$

$5a = 18.105 - 26.181b$

$5a = 18.105 - 26.181 \times 0.67623$

$5a = 18.105 - 17.704$

$5a = 0.401$

$a = 0.0802$

ie: $80 + $0.676 x GTM (000,000)

Simple Correlation - Weighted on Gross Ton Miles

Railroad	Weighting Factor Gross Ton Miles (Hundred Million) w	Per Mile of Track GTM Expenses (Millions) xw	(Thousands) yw	xyw	x^2w
A	0.255	0.465	0.297	0.541	0.848
B	0.579	2.394	1.790	7.398	9.895
C	1.018	7.641	4.985	37.419	57.354
D	1.301	7.747	5.318	31.672	46.156
E	1.534	10.711	7.708	52.120	72.428
Total	4.737	28.958	20.098	129.150	186.661

Normal Equations:

$\Sigma wy = Na + b\Sigma wx$

$\Sigma wxy = a\Sigma wx + b\Sigma wx^2$

(1) $20.098 = 4.737a + 28.958b$ $(28.958 \div 4.737 = 6.113)$

(2) $129.150 = 28.958a + 186.661b$

(1') $122.859 = 28.958a + 177.020b$ (1') = (1)x6.113

$6.291 = 9.641b$

$b = 0.65252$

$4.737a = 20.098 - 28.958b$

$4.737a = 20.098 - 28.958 \times 0.65252$

$4.737a = 20.098 - 18.896$

$4.737a = 1.202$

$a = 0.25374$

ie: \$254 + \$0.653 x GTM (000,000)

Simple Correlation - Weighted on Miles of Track

Railroad	Weighting Factor Miles of Track (ten thousand) w_1	Per Mile of Track GTM (Millions) xw_1	Expenses (Thous) yw_1	xyw_1	x^2w_1
A	1.397	2.548	1.625	2.963	4.648
B	1.401	5.792	4.330	17.902	23.943
C	1.357	10.186	6.645	49.879	76.453
D	2.185	13.012	8.932	53.192	77.484
E	2.343	15.843	11.401	77.094	107.134
Total	8.683	47.381	32.933	201.030	289.662

Normal Equations:

$\Sigma w_1 y = Na + b\Sigma w_1 x$

$\Sigma w_1 xy = a\Sigma w_1 x + b\Sigma w_1 x^2$

(1) $32.933 = 8.683a + 47.381b$ $(47.381 \div 8.6863 = 5.4568)$

(2) $201.030 = 47.381a + 289.662b$

(1') $179.709 = 47.381a + 258.549b$ (1') = (1) x 5.4568

$21.321 = 31.113b$

$b = 0.68527$

$8.683a = 32.933 - 47.381b$

$8.683a = 32.933 - 47.381 \times 0.68527$

$8.683a = 32.933 - 32.469$

$8.683a = 0.464$

$a = 0.053433$

i.e. \$53 + \$0.685 x GTM (000,000)

Multiple Correlation

Railroad	GTM (Billions) x_3	Expenses Excluding Depreciation (Millions) x_1	Miles of Track (Thous) x_2	x_2^2	x_3^2	x_1x_2	x_1x_3	x_2x_3
A	25.476	16.240	13.965	195.021	649.027	226.792	413.730	355.772
B	57.914	43.302	14.010	196.280	3354.031	606.661	2507.792	811.375
C	101.836	66.432	13.567	184.064	10370.571	901.283	6765.169	1381.609
D	130.113	89.324	21.848	477.335	16929.393	1951.551	11622.214	2842.709
E	158.436	114.010	23.432	549.059	25101.966	2671.482	18063.288	3712.472
Total	473.775	329.308	86.822	1601.759	56404.988	6357.769	39372.193	9103.937

(1) $\Sigma x_1 = Na + b\Sigma x_2 + c\Sigma x_3$

(2) $\Sigma x_1 x_2 = a\Sigma x_2 + b\Sigma x_2^2 + c\Sigma x_2 x_3$

(3) $\Sigma x_1 x_3 = a\Sigma x_3 + b\Sigma x_2 x_3 + c\Sigma x_3^2$

(1) 329.308 = 5a + 86.822b + 473.775c (86.822 ÷ 5 = 17.3644)
(2)6357.769 = 86.822a + 1601.759b + 9103.937c
(3)39372.193= 473.775a + 9103.937b + 56404.988c (86.825 ÷ 473.775 = 0.183286)

(1') 5718.036 = 86.822a + 1507.612b + 3226.819c (1')=(1) x 17.3644
(2) 6357.769 = 86.822a + 1601.759b + 9103.937c
(2-1') 639.533 = 94.147b + 877.118c (94.142 ÷ 66.628=1.41302)

(2) 6357.769 = 86.822a + 1601.759b + 9103.937c
(3') 7215.348 = 86.822a + 1668.387b + 10336.778c(3')=(3) x 0.18328
(3'-2) 857.579 = 66.628b + 1232.841c

(2-1') 639.533 = 94.147b + 877.118c
(3'-2) 1211.776 = 94.147b + 1742.029c (3'-2)= (3'-2) x1.41302
572.243 = 864.911c

c = 0.66162
94.147b = 639.533 - 877.118c
94.147b = 639.533 - 877.118 x 0.66162
94.147b = 59.214
b = 0.62895
5a = 329.308 - 86.822b - 473.775c
5a = 329.308 - 86.822 x 0.62895 - 473.775 x 0.66162
5a = - 38.758
a = -$7.75160

ie; - $7,752,000 + $0.629 x miles of total track (000) + $0.662 x GTM(000,000)

Report on Assignment 4

Potential Applications of Electronic Computers to Railway Engineering and Maintenance Problems in Research, Design, Inventory, etc.

Collaborating with Committees 11 and 30, and Informally with the Railway Systems and Procedures Association

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This is a progress report, submitted as information.

One of the most noticeable and logical changes that has occurred in industry has been the application to business problems of electronic data-processing equipment. In the development of this trend, computers were first used by the government to solve problems which required high-speed calculating ability. The earliest applications in private industry were primarily in the field of accounting, with emphasis on payroll and billing where voluminous, simple calculations were made. As the computer technology advanced it was found that repetitive engineering calculations and very complicated calculating processes could be undertaken with such equipment.

The railroad industry, like other industries, has concentrated its applications of computers mainly to accounting problems. It is believed that with the acquisition of electronic data-processing equipment, the railroads will find sufficient time on this equipment to solve engineering problems which were not previously solvable because of time and manpower requirements.

In the discussion which follows it is necessary to use words which have taken on somewhat special meanings in the computer field. A short glossary is given in Appendix A to cover those words used in this report.

1. Organization and Use of Computers

The availability of a computer to the engineering departments varies considerably among the railroads. In most companies which already have computers installed, the control is under either the accounting department or a special department established for processing data. In some of these companies there is free machine time on the second and third shifts and during off-peak accounting periods, which may be used by the engineering departments. Under the organization of some installations the programming and operation must be done by the department in charge of the computer.

Aside from the medium and large computers which are generally installed for accounting purposes, there are a number of small computers now on the market which are designed especially for engineering applications. These may be used advantageously by an engineering department where the organization of the large computer installation handicaps the engineering department or where the larger installation is already fully utilized. Before installing a computer of any size a thorough study is warranted to assure that the intended use justifies a computer and that the computer selected is sized correctly for the intended application. In the early years of computer application to industry, several firms found that after installing a computer the expected benefits could have been had just by rearranging the methods of doing the work.

There are computer service installations which will do work on an hourly charge or contract price basis. Some of these service bureaus are maintained in the principal cities by the major computer manufacturers, some by universities, and some are private firms organized solely for this purpose.

In any of these cases, the engineering department has to determine how much of the actual programming and machine operation it should do within the department, and how much it should have done by people outside the department.

Programming and machine operation are skills which are fully developed only by practice. Where an engineering department has not developed sufficient demand for computer application to keep up the skill of its own personnel, it will benefit from using outside programmers. However, having the work done by outside programmers still requires engineering personnel to spend time (sometimes large amounts) explaining the problem to the programmer. Even with the most detailed explanations there frequently occurs misunderstanding because the programmer is not familiar with the engineering nomenclature and principles involved, and the engineering personnel are not familiar with the computer's limitations and capabilities.

If there is sufficient work in the engineering department to develop an internal staff for setting its problems into machine programs, this method will probably optimize the benefits of the computer to the engineering department. The present developments in automatic coding routines offer advantages to engineering departments in lessening the time-consuming parts of writing detailed program instructions and debugging, and greatly reduce the amount of training necessary to familiarize personnel with the machine. In this respect, these automatic coders replace much of the skill previously required.

One company reports that by using the automatic coding routine available for one of the medium-size computers they have trained engineering personnel to write their own programs and operate the machine in one day—four hours learning the programming technique and four hours of machine familiarity.

We might note that, generally, programs written with automatic coders are less efficient of machine time, but for most engineering applications this loss of machine efficiency is more than offset by the increase in programming efficiency. Aside from the automatic coding routines, there already exists rather extensive libraries of programs which the engineering department can use; however, as a general rule, it is highly desirable if the engineering department has sufficient knowledge of machine use to be able to determine that any library program actually meets their requirements.

2. Types of Computer Equipment Available

Electronic computers are essentially high-speed calculators with various information storage and comparing abilities. Appendix B is a descriptive listing of digital computers with information about operating characteristics.

3. Applications of Electronic Data Computer to Engineering Problems

There is a large bibliography of references and libraries of programs for computers. These are available either through user associations or from computer manufacturers.

Without describing them in detail, the engineering problems which have been solved through the use of computers are listed below.

a. Aeronautical Engineering

Systems evaluation
Curve fitting

Factor analysis
Stress analysis
Vibration analysis
Fuel–oil system analysis
Electrical circuit analysis

b. Civil Engineering

(1) Soils Engineering
Pressure distribution in layered media
Design charts for relief-well systems of partially penetrating wells
Freezing and thawing of soils

(2) Highway and Railway Engineering and Surveying
Cut and fill
Traverse closure
Traverse adjustment (compass and transit rules, least squares)
Transformation of coordinates (Mercator, Lambert, Local Plane, etc.)
Photogrammetric data reduction
Estimating

(3) Structural and Mechanical Engineering
Truss analysis, stresses and deflections
Analysis of reinforced concrete, bending and direct stresses
Heat flow in concrete
Shell analysis, stress distribution
Analysis of rigid frames, moment distribution
Effects of foundation settlements
Temperature stresses
Arch analysis and design
Cam design
Critical speeds
Pipe-stress analysis
Moments of inertia
Air conditioning

(4) Hydraulic Engineering and Hydrology
Water management of a multipurpose reservoir system
Flood routing
Backwater profiles
Hydraulic network analysis—(Hardy Cross)
Flow of ground water
Flood or flow forecasting
Flood frequency analysis
Wind–wave analysis

c. Chemical Engineering

Crude oil evaluation
Mass spectrometer analysis
Process simulation

d. Electrical and Electronic Engineering and Communications

Circuit analysis and design
Antennae design

Radar echos
Radio interference
Filter analysis

e. Mechanical Design

Critical speed calculations for rotating shafts (Prohl method)
Properties of combustion constituents calculation
Gas turbine unbalanced torque calculation

f. Public Utilities

Life expectancy of equipment
Transmission losses
Demand forecasting
Flood control
Pipe line design
Calibration of standard meters
Calculation of depreciation tables

In continuing its assignment, your committee hopes to investigate the possibility of setting up a centralized library of computer programs designed to solve railway engineering problems. In this way, it is believed that duplication of effort in parallel railroad fields will be minimized.

Also, your committee hopes to find some programs of sufficient general interest to present them in the Proceedings as concrete examples of the uses of computers in railway engineering.

The use of electronic data-processing equipment for the solution of railway engineering problems is in its infancy. Initially, computers no doubt will be viewed as time savers and labor savers; that is, application will be for repetitive processes. However, as railway engineers become facile in the use of computers it is believed that problems which had been considered insoluble will be programmed and solved. Computers give the railway engineer a tool with which he will not only be able to solve complex engineering problems quickly and in much greater volume, but it will allow economic evaluations of the effects of solutions to certain engineering problems as related to other operations. This will allow the engineer to determine the *best* answer rather than the best answer of a few alternative answers.

APPENDIX A

The following definitions are abstracted from the "First Glossary of Programming Terminology" in a Report to the Association for Computing Machinery, June 1954.

Code (noun)—A system of symbols and of the rules for their use in representing information.

Computer Code (Machine Code)—the code representing the operations built into the hardware of the computer.

Instruction Code—the symbols, names, and definitions of all the instructions which are directly intelligible to a given computer or a given executive routine.

Operation Code—that part of an instruction which designates the operation to be performed.

Pseudo-Code—an arbitrary code, independent of the hardware of a computer, which must be translated into computer code if it is to direct the computer.

Pulse Code—sets of pulses to which particular meanings have been assigned; binary representation of characters.

Code (verb)—to prepare problems in computer code in pseudo-code for a specific computer.

Coding—the list, in computer code or in pseudo-code, of the successive computer operations required to solve a given problem.

Absolute, Relative, or *Symbolic Coding*—coding in which one uses asbsolute, relative, or symbolic addresses, respectively.

Automatic Coding—any technique in which a computer is used to help bridge the gap between some "easiest" form, intellectually and manually, of describing the steps to be followed in solving a given problem and some "most efficient" final coding of the same problem for a given computer. Two basic forms, defined under Routine, are Compilation and Interpretation.

Program (noun)—a plan for the solution of a problem. A complete program includes plans for the transcription of data, coding for the computer and plans for the absorption of the results into the system. The list of coded instructions is called a *routine.*

Program (verb)—to plan a computation or process from the asking of a question to the delivery of the results, including the integration of the operation into an existing system. This programming consists of planning and coding, including numerical analysis, systems analysis, specification of printing formats, and any other functions necessary to the integration of a computer in a system.

Automatic Programming—any technique in which the computer is used to help plan as well as to help code a problem.

Optimum Programming—minimal latency coding.

Routine—a set of coded instructions arranged in proper sequence to direct the computer to perform a desired operation or series of operations.

Executive Routine (Master Routine)—a routine designed to process and control other routines. A routine used in realizing automatic coding

Compiler (Compiling Routine)—an executive routine which *before* the desired computation is started, translates a program expressed in pseudo-code into machine code (or into another pseudo-code for further translation by an interpreter.) In accomplishing the translation, the compiler may be required to decode, convert, select, generate, allocate, assemble, record.

Interpreter (Interpretive Routine)—an executive routine which, as the computation progresses, translates a stored program expressed in some machine—like pseudo-code into machine code and performs the indicated operations by means of subroutines, as they are translated.

Minimal Latency Routine—especially in reference to serial storage systems, a routine so coded, by judicious arrangement of data and instructions in storage, that the actual latency is appreciably less than the expected random access latency.

APPENDIX B

Output Type	Output Speed	Application	Instruction Type Address
Paper Tape	60 Char./Sec.	CB; S	1
Mag. Tape	10000 Char./Sec.		
Flexowriter	10 Char./Sec.		
Card Converter	100 Cards/Min.		
Card Punch	11 Char./Sec.	S-	2
Typewriter	8 Char./Sec.		
Punch	60 Char./Sec.		
Mag. Tape	430 Char./Sec.		
Printer	600 Lines/Min.	GP	3
Mag. to Paper Tape	20 Char./Sec.		
Mag. to Teletype	50 Char./Sec.		
Paper to Typewriter	9 Char./Sec.		
Mag. to Typewriter	4 Min/Inquiry		
Printer	24 Dig./Sec.	CB;S	1
Paper Tape	0.33 Sec. Punch		
Paper Tape Punch	10 Char./Sec.	S;Portable	1
Readout Panel	66 Milsec./Dig.		
Typewriter	Manual		
Punched Cards	100/Min.	CB;S	3, 4
Printing	900 Lines/Min.		
Paper Tape	10 Char./Sec.		
Mag. Tape	60000 Dig/Sec.		
Paper Tape	Input Converter		
Paper Tape	Output Converter		
Typewriter	10 Char/Sec.	GP	1
Paper Tape	60 Dig/Sec.		
Mag. Tape	6000 Dig/Sec.		
Cards	1800 Char/Min.		
Punched Cards	10 Milsec/Transfer	CB;S	1
Paper Tape	60 Char/Sec.		
Mag. Tape	25000 Dig/Sec.		
Paper Tape	60 Dig/Sec.	GP	2
Line Printer	150 Lines/Min.		
Punched Cards	100 Cards. Min.		
Printer	10 Char/Sec.	C	-
Paper Tape	2 Dig/Sec.		
Typewriter	7.5 Dig./Sec.	S	3
Typewriter	8 Char/Sec.	S	2
Paper Tape	60 Char/Sec.		
Mag. Tape	400 Char/Sec.		
Typewriter	8 Char/Sec.	C;S	2
Paper Tape	8 or 60 Char/Sec.		
Mag. Tape	6000 Char/Sec.		
Punch Cards			

APPENDIX B

LISTING OF DIGITAL COMPUTERS

Manufacturer and Type	Model	Average Price For System	Average Rental Per Month Dollars	Space For Computer & Important Units Cubic Ft.	Divide Time Including Access Micro-seconds	Input Type	Input Speed	Storage Type	Storage Words	Storage Access Micro-seconds	Output Type	Output Speed	Application	Instruction Type Address
Logistics Research, Inc.; ALWAC	III E	C	B	158	17000 to 25000	Paper Tape Mag. Tape Flexowriter Card Converter	200 Char./Sec. 10000 Char./Sec. Manual 100 Cards/Min.	Mag. Drum	32	1000 to 16000	Paper Tape Mag. Tape Flexowriter Card Converter	60 Char./Sec. 10000 Char./Sec 10 Char./Sec. 100 Cards/Min.	CB; S	1
Bendix Computer Div.; BENDIX	G 15	B	B	30.5	16000 to 33000	Paper Tape Card Punch Mag. Tape	275 Char./Sec. 17 Char./Sec. 430 Char./Sec.	Mag. Drum Mag. Drum	2160 16	14500 540	Card Punch Typewriter Punch Mag. Tape	11 Char /Sec. 8 Char./Sec. 60 Char./Sec. 430 Char./Sec.	S-	2
RCA BIZMAC	-	H	-	3800	Varies Prog.	Card to Tape Key to Paper Tape Paper to Mag.Tape	400 Cards/Min. 5000 Strokes/Hr. 200 Char./Sec.	Mag. Core Mag. Drum Mag. Tape	8192 Digits 32736 Dig. Indefinite	20/Char. 5120 5000	Printer Mag. to Paper Tape Mag. to Teletype Paper to Typewriter Mag.to Typewriter	600 Lines/Min. 20 Char./Sec. 50 Char./Sec. 9 Char./Sec. 4 Min/Inquiry	GP	3
Burroughs Corp.; BURROTRON	E-101	B	B	Desk Size	250,000	Keyboard Paper Tape	Manual 0.5 Sec.to Read	Mag. Drum Paper Tape	220	8500	Printer Paper Tape	24 Dig./Sec. 0.33 Sec.Punch	CB;S	1
Autonetics Div.; RECOMP	CP-266	D	-	5.7	21500	Paper Tape Typewriter Keyboard	37 Char./Sec. Manual Manual	Rot.Mag.Disk Rot.Mag.Disk	2048 16	1000 - 32500 1000 - 2500	Paper Tape Punch Readout Panel Typewriter	10 Char./Sec. 66 Milsec./Dig. Manual	S;Portable	1
DATAmatic Corp.; DATAMATIC	1000	G	G	550 Sq.Ft.	2304	Punch Cards Paper Tape Keyboard Mag. Tape	900 Cards/Min. 10 Char./Sec. Manual 60000 Dig/Sec.	Mag. Cores Mag. Cores Mag. Tape	2000 248 37200000 Dig/Reel	12 20	Punched Cards Printing Paper Tape Mag. Tape Paper Tape Paper Tape	100/Min. 900 Lines/Min. 10 Char./Sec. 60000 Dig/Sec. Input Converter Output Converter	CB;S	3, 4
Electro Data Div.; DATATRON	205	E	D	181	12680	Paper Tape Keyboard Mag.Tape Cards	540 Dig/Sec Manual 6000 Dig/Sec. 21120 Dig/Sec.	Mag. Drum Mag. Tape Data File	4080 400000 2000000	850 240000000 24000000	Typewriter Paper Tape Mag.Tape Cards	10 Char/Sec. 60 Dig/Sec. 6000 Dig/Sec. 1800 Char/Min.	GP	1
	220	F	F	1200 Sq.Ft.	4000	Paper Tape Mag.Tape Punch Cards	1000 Char/Sec. 1400000 Words/Sec. 7 Milsec/Transfer	Mag. Core Mag. Tape	2000-10000 Words	.10	Punched Cards Paper Tape Mag. Tape	10 Milsec/Transfer 60 Char/Sec. 25000 Dig/Sec.	CB;S	1
Business Machines Div.; DIANA	-	F	G	1500 Sq.Ft.	4830	Paper Tape Punch Cards Typewriter	60-300 Dig/Sec. 100-500 Cards/Min. Manual	Mag.Core Hi-Sp.Drum File Drums	200-10000 Char. 58500 Char. 2 to 625 x 106 Char.	34 11000 197000	Paper Tape Line Printer Punched Cards	60 Dig/Sec. 150 Lines/Min. 100 Cards. Min.	GP	2
Underwood Corp.; ELECOM	50	A	A	50	None	Keyboard Paper Tape	Manual 20 Dig/Sec.	Mag. Drum Mag. Drum	100 3	33000 325	Printer Paper Tape	10 Char/Sec. 2 Dig/Sec.	C	-
	100	B	-	120 Sq.Ft.	25-50 op/Sec.	Typewriter Paper Tape	Manual 7.5 Dig/Sec.	Mag. Drum Mag. Tape	512 60000	20000 -	Typewriter	7.5 Dig./Sec.	S	3
	120	D	D	200	18900(Excl.Acc.)	Typewriter Paper Tape Mag.Tape	8 Char/Sec. 8 to 400 Char/Sec. 400 Char/Sec.	Mag. Drum Mag.Drum	1000 to 10000 10 to 100	8300 1670	Typewriter Paper Tape Mag. Tape	8 Char/Sec. 60 Char/Sec. 400 Char/Sec.	S	2
	125,125FP	F	F	525	22000	Typewriter Paper Tape Mag.Tape Punch Cards	8 Char/Sec. 8 to 400 Char/Sec 6000 Char./Sec.	Mag. Drum Mag.Drum	4000 to 10000 50 to 100	8300 1670	Typewriter Paper Tape Mag. Tape Punch Cards	8 Char/Sec. 8 or 60 Char/Sec. 6000 Char/Sec.	C;S	2

Access Micro-seconds	Output Type	Output Speed	Application	Instruction Type Address
-	Teleprinter	7 Char/Sec.	S	1
31200	Tape Punch	25 Char/Sec.		
	Printer	150 Lines/Min.		
Rapid	Tape Punch	25 Char/Sec.	S	1
8000	Teleprinter	6.7 Char/Sec.		
Rapid	Paper Tape	25 Char/Sec.	S	2
8000	Teleprinter	-		
3	Punched Tape	6 to 12 Words/Sec.	S	3
60000000	Mag. Tape	250 Words/Sec.		
	Flexowriter	1 Word/Sec.		
760	Printer	100to150 Lines/Min.	B;S	1, 2
600000	Summary Punch	50 Cards/Min.		
800000				
500	Card Reader Punch	100 Cards/Min.	B; S	1, 2
520	Card Reader Punch	100 Cards/Min	B; S	1,2
220	Card Reader Punch	155 Cards/Min.	B; S	1,2
-	Typewriter	-	S	-
	Tape Punch	-		
	Cathode Tube	-		
-	Keyboard	-	-	-
96 - 4800	Card Recorder	100 Cards/Min	C; S	2
96	Mag. Tape	15000 Char/Sec.		
	Printer	150 Lines/Min.		
)0000/60 Words	Printer	1000 Lines/Min.		
12	Card Reader	100 Cards/Min.	C; S	1
96to12000	Printer	150 Lines/Min.		
	Cathode Tube	8300 Pts./Sec.		
	Mag. Tape	15000 Char/Sec.		
	Tape to Card	100 Cards/Min.		
	Tape to Printer	150 Lines/Min.		
17	Punched Card	100 Cards/Min.	C;S	1
)00-40N/Char.	Mag. Tape	15000 Char/Sec.		
)000-67N/Char.	Printer	150 Lines/Min.		
-	Card Punch	100 Cards/Min.	C; S	1
-	Mag. Tape	100 Cards/Min.		
	Printer	150 Lines/Min.		
	CRT Recorder	8000 Pts/Sec.		
7500	Paper Tape	10 Char/Sec.	S	1
	Flexowriter	10 Char/Sec.		

LISTING OF DIGITAL COMPUTERS

Manufacturer and Type	Model	Average Price For System	Average Rental Per Month Dollars	Space For Computer & Important Units Cubic Ft.	Divide Time Including Access Micro-seconds	Input		Storage			Output			Instruction Type Address
						Type	Speed	Type	Words	Access Micro-seconds	Type	Speed	Application	
Ferranti Ltd.; FERRANTI	Mark I	F	-	4000	None	Paper Tape	200 Char/Sec.	Electrostatic Mag. Drum	768 32768	- 31200	Teleprinter Tape Punch Printer	7 Char/Sec. 25 Char/Sec. 150 Lines/Min.	S	1
	Mercury	F	-	216	3500	Paper Tape	200 Char/Sec.	Mag. Cores Mag. Drums	1024 16384	Rapid 8000	Tape Punch Teleprinter	25 Char/Sec. 6.7 Char/Sec.	S	1
	Pegasus	F	-	250	5500	Paper Tape	200 Char/Sec.	Mag'tve Delay Mag. Drums	55 4608	Rapid 8000	Paper Tape Teleprinter	25 Char/Sec. -	S	2
RCAet al; FLAC	II	G	-	Room 50' x 26'	2352	Paper Tape Mag.Tape Flexowriter	300to600 Char/Sec. 250 Words/Sec. 1 Word/Sec.	Mag. Core Mag.Tape Bin	4096 400000	3 60000000	Punched Tape Mag. Tape Flexowriter	6 to 12 Words/Sec. 250 Words/Sec. 1 Word/Sec.	S	3
International Business Machines I B M	CPC	-	C	375	15480(Excl.Acc.)	Card Reader	100-150 Cards/Min	Elect.Tubes Accumulator Mechanical	9 6 48	760 600000 800000	Printer Summary Punch	100to150 Lines/Min. 50 Cards/Min.	B;S	1, 2
	604	B	A	73.9	17000(Excl.Acc.)	Card Reader Punch	100 Cards/Min	Elect. Tubes	9	500	Card Reader Punch	100 Cards/Min.	B; S	1, 2
	607	B	A	178.9	15700 (Excel. Access)	Card Reader Punch	100 Cards/Min.	Elect. Tubes	37	520	Card Reader Punch	100 Cards/Min	B; S	1,2
	608	E	B	160	13420 (Excel. Access)	Card Reader Punch	155 Cards/Min.	Mag. Cores	40	220	Card Reader Punch	155 Cards/Min.	B; S	1,2
International Business Machines; I B M	610	C	B	31	39 Per Min.	Keyboard Tape Reader	Manual 15/Dig./Sec.	Mag. Drum	84	-	Typewriter Tape Punch Cathode Tube	- - -	S	-
	632	A	-	5 Sq.Ft.	-	Keyboard	-	Mag. Core	-	-	Keyboard	-	-	-
	650	F	D	270	6000 - 23400 (Excl.Access)	Punch Card	200 Cards/Min	Mag. Drum	1000 2000 Words	96 - 4800	Card Recorder	100 Cards/Min	C; S	2
						Mag. Tape	15000 Char/Sec.	Mag.Core Mag. Tape Disc.Ramac	60 500000/Unit 600000	96 800000/60 Words	Mag. Tape Printer Printer	15000 Char/Sec. 150 Lines/Min. 1000 Lines/Min.		
	704	H	G	3000 Sq.Ft.	228(Excl.Acc.)	Card Reader Mag. Tape Card to Tape	150-250 Cards/M. 15000 Char/Sec. 250 Cards/Min.	Mag. Core Mag. Drum	8192 8192 or 16384	12 96to12000	Card Reader Printer Cathode Tube Mag. Tape Tape to Card Tape to Printer	100 Cards/Min. 150 Lines/Min. 8300 Pts./Sec. 15000 Char/Sec. 100 Cards/Min. 150 Lines/Min.	C; S	1
	705	H	G	2000 Sq.Ft.	527(20Dig.Nos.)	Mag. Tape Punch Cards	75 in/Sec. 250 Cards/Min.	Mag. Core Mag. Drum Mag. Tape	40000 Char. 60000 Char. 576000 Char.	17 8000-40N/Char. 10000-67N/Char.	Punched Card Mag. Tape Printer	100 Cards/Min. 15000 Char/Sec. 150 Lines/Min.	C;S	1
	709	H	G	3000Sq.Ft.	216	Card Reader Mag. Tape	250 Cards/Min. 90000 Dig/Sec.	Mag. Core Mag. Drum	4096-32768 8192 to 16384	- -	Card Punch Mag. Tape Printer CRT Recorder	100 Cards/Min. 100 Cards/Min. 150 Lines/Min. 8000 Pts/Sec.	C; S	1
Librascope,Inc. LGP	30	B	B	22	24000	Paper Tape Flexowriter	10 Char/Sec. Manual	Mag. Drum	4096	7500	Paper Tape Flexowriter	10 Char/Sec. 10 Char/Sec.	S	1

Access Micro-seconds	Output Type	Output Speed	Application	Instruction Type Address
15000 30000	Graph Plotter Dig.to Analog	31 Inc/Sec. 31 Inc/Sec.	Differential Equations Simulation	-
300000	Typewriter	7 Char/Sec.	Inventory Control	1
50000 50000	Typewriter	10 Char/Sec.	Inventory Control	1
$3x10^6$ Trans/Hr.	Keyset Telephone	- -	Stock Market	-
Random	Paper Tape Office Machs.	10 Char/Sec.	Inventory	-
Random	Keyset	1.2-3.3 Trans/Sec.	Railroad & Air Trans-port	
200 to 10000	Paper Tape	600 Dig/Min.	S	1
8	Paper Tape Mag. Tape Typewriter	- - -	Mobile Mil. Field. Rugged	
25000	Paper Tape Punch Cards	200 Char/Sec. 4 Cards/Sec.	Business Data	1
7500	Punch Tape Punch Cards	60 Char/Sec. 600 Cards/Min.	B	1
8000 576 288	Paper Tape Punch Card	70 Char/Sec. 360 Cards/Min.	Translating; GP	1
17 32	Paper Tape	600 Char/Min.	Inventory	1
16670	Printer Punch Tape Punch Card	10 Char./Sec. 10 Char/Sec. 17 Char/Sec.	S	4
12500 6000	Mag. Tape Flexowriter Paper Tape	600 Char/Sec. 10 Char/Sec. 10 Char/Sec.		
12500	Paper Tape Punch Mag. Tape Punch Cards	10 Char/Sec. 60 Char/Sec. 600 Char/Sec. 4000 Char/Min.	GP; S	3
-	Paper Tape Printer Mag. Tape	60 Char/Sec. 600 Lines/Min 15000 Char/Sec.	C; S	Multi.
19 to 305 19 to 4 Mins.	Typewriter Mag. Tape	5 Dig/Sec. 400 Words/Sec.	S	4

LISTING OF DIGITAL COMPUTERS

Manufacturer and Type	Model	Average Price For System	Average Rental Per Month Dollars	Space For Computer & Important Units Cubic Ft.	Divide Time Including Access Micro-seconds	Input Type	Input Speed	Storage Type	Storage Words	Storage Access Micro-seconds	Output Type	Output Speed	Application	Instruction Type	Instruction Address
Litton Industries LITTON	20 40	A	A	0.5	DDA	Tape Fill Curve Follower Manual	20 Integ/Min. 62 Increm/Sec. 2 Integ/Min	Mag. Drum Mag. Drum	20 40	15000 30000	Graph Plotter Dig.to Analog	31 Inc/Sec. 31 Inc/Sec.	Differential Equations Simulation		-
ELECTRONICS CORP.; MAGNEFILE	B D	A C	-	9 Sq.Ft. 15 Sq. Ft.	-	Keyboard Keyboard	4 Char/Sec. 4 Char/Sec.	Mag. Drum Mag. Drum Mag. Drum	4040 8000 500	300000 50000 50000	Typewriter Typewriter	7 Char/Sec. 10 Char/Sec.	Inventory Control Inventory Control		1 1
Telergister Corp.; MAGNETRONIC	BID Asked	Special	-	-	-	Keyset Telephone	- -	Mag. Drum	100000 Digits	$8x10^6$ Trans/Hr.	Keyset Telephone	- -	Stock Market		-
	Inventory	F	-	-	-	Paper Tape Punch Cards Tape Punch	10 Char/Sec. - 20 Char/Sec.	Mag.Drum	1500000 Dig.	Random	Paper Tape Office Machs.	10 Char/Sec.	Inventory		-
	Reservisor MRA,MRR,MAA	Spc. Purpose	-	-	-	Keyset	1.2-3.3 Trans./Sec.	Mag.Drum	1to3.5 Megabits	Random	Keyset	1.2-3.3 Trans/Sec.	Railroad & Air Transport		
Marchant,Inc. MINIAC	C II	D	-	91	25600	Paper Tape Keyboard	600 Char/Min. Manual	Mag. Drum	4096	1200 to 10000	Paper Tape	600 Dig/Min.	S		1
Sylvania,Inc.; MOBIDIC	-	-	-	Std.Military Trailer	150	Paper Tape Mag. Tape Typewriter	- - -	Mag. Core	4096	8	Paper Tape Mag. Tape Typewriter	- - -	Mobile Mil. Field. Rugged		
Mountain Systems; MODAC	404	E	-	120	None	Paper Tape Punch Cards	200 Char/Sec. 4 Cards/Sec.	Mag. Drum	20000	25000	Paper Tape Punch Cards	200 Char/Sec. 4 Cards/Sec.	Business Data		1
	410	E	-	40	700(Excl.Acc.)	Punch Tape Punch Cards	400 Char./Sec. 600 Cards/Min.	Mag. Drum	5000	7500	Punch Tape Punch Cards	60 Char/Sec. 600 Cards/Min.	B		1
	414	F	-	240	8000	Paper Tape Punch Cards	- 360 Cards/Min.	Mag. Drum Mag. Drum Mag. Cores	6000 4 2	8000 576 288	Paper Tape Punch Card	70 Char/Sec. 360 Cards/Min.	Translating; GP		1
	5014	D	-	30	None	Paper Tape	600 Char/Min.	Mag. Drum Shift Reg.	10000 1	17 32	Paper Tape	600 Char/Min.	Inventory		1
Monroe Calc.Mach. Co.; MONROBOT	VI	-	-	-	600000	Keyboard Punch Tape	Manual 10/Sec.	Mag. Drum	200	16670	Printer Punch Tape Punch Card	10 Char./Sec. 10 Char/Sec. 17 Char/Sec.	S		4
National Cash Register Company NCR	CRC 102A	C	C	135	38500	Flexowriter Paper Tape Mag. Tape	Manual 10 Char/Sec. 1.6 Char/Milsec	Mag. Drum Mag. Tape	1024 112800/Reel	12500 6000	Mag. Tape Flexowriter Paper Tape	600 Char/Sec. 10 Char/Sec. 10 Char/Sec.			
	102D	C	C	250 Sq.Ft.	21100-53200	Paper Tape Paper Tape Mag. Tape Keyboard Punch Cards	10 Char/Sec. 200 Char/Sec. 600 Char/Sec. Manual 4000 Char/Min.	Mag. Drum Mag. Tape	1024 102000/Reel	12500	Paper Tape Punch Mag. Tape Punch Cards	10 Char/Sec. 60 Char/Sec. 600 Char/Sec. 4000 Char/Min.	GP; S		3
National Cash Register Co.; NCR	304	H	-	1600 Sq.Ft.	4200(20 Digit Nos.)	Punch Cards Paper Tape Mag. Tape	1000 Cards/Min. 1000 Char/Sec. 15000 Char/Sec.	Mag. Core Mag. Tape Mag. Tape	1000-4000 400000 600000	-	Paper Tape Printer Mag. Tape	60 Char/Sec. 600 Lines/Min 15000 Char/Sec.	C; S		Multi.
Raytheon Mfg.Co.; RAYDAC	-	H	-	17600	470 to 1620	Keyboard Mag. Tape	14 Words/Min. 400 words/Sec.	Delay Line Mag. Tape	2176 400000	19 to 305 19 to 4 Mins.	Typewriter Mag. Tape	5 Dig/Sec. 400 Words/Sec.	S		4

Access Micro-seconds	Output Type	Output Speed	Application	In-struction Type Address
425 - 9350	Flexowriter	10 Char/Sec.	B; S	1
-	Punch Cards	100 Cards/Min.		
	Mag. Tape	700 Dig/Sec.		
-	Typewriter	-	GP	1
-	Printers	-		
20/5 Dig.	Paper Tape	60 Char/Sec.	C; S	1
40.4 to 404	Mag. Tape	128000 Char/Sec.	GP	1
	Printer	10 InSec.		
	Printer	10 Char/Sec.		
	Printer	600 Lines/Min.		
	Tape to Card	120 Cards/Min.		
	Mag. Tape to Paper	- 50 Char/Sec.		
	Transrecorder	90 Char/Sec.		
20	Mag. Tape	-	GP	1
	Uniprinter	10 Char/Sec.		
	Hi-Speed Printer	600 Lines/Min.		
	Tape to Card	120 Cards/Min.		
	Mag. to Paper Tape	90 Char/Sec.		
-	Card Punch	-	B; S	3
-	Card Punch	-	B; S	3
iar. Random	Card Punch	-	File	-
	Keyboard	-	Sort	
	Paper Tape	-	Complete	
	Mag. Tape	-		
8	Mag. Tape	2130 Words/Sec.	S	2
17500	Printer	600 Lines/Min.		
	Punch	60 Frames/Sec.		
	Reproducer	120 Cards/Min.		
	Flexowriter	Monitor		

LISTING OF DIGITAL COMPUTERS

Manufacturer and Type	Model	Average Price For System	Average Rental Per Month Dollars	Space For Computer & Important Units Cubic Ft.	Divide Time Including Access Micro-seconds	Input Type	Input Speed	Storage Type	Storage Words	Storage Access Micro-seconds	Output Type	Output Speed	Output Application	In-struction Type Address
U.S.Rea.Inc.; READIX	-	E	D	125	9350 - 44000	Flexowriter Punch Cards Mag. Tape	10 Char/Sec. 100 Cards/Min. 700 Dig/Sec.	Mag. Drum Mag. Tape	4000 50000	425 - 9350 -	Flexowriter Punch Cards Mag. Tape	10 Char/Sec. 100 Cards/Min. 700 Dig/Sec.	B; S	1
Philco Corp.; Transac	S2000	H	G	48	80(Excl. Acc.)	Punched Card Pref. Tape Mag. Tape	1200Words/Min. WO Char/Sec. 750 Words/Sec.	Mag. Core Mag. Drum	4096 16384-24576	- -	Typewriter Printers	- -	GP	1
Burroughs Corp.; UDEC	II,III	F	-	31 Racks	30000(Excl. Access)	Paper Tape	120 Char/Sec.	Mag. Core Mag. Drum	1000	20/5 Dig.	Paper Tape	60 Char/Sec.	C; S	1
Remington Rand; UNIVAC	I	H	G	943	3950	Mag. Tape Keyboard Card to Tape Paper to Mag. Tape Transrecorder	12800 Char/Sec. Manual 240 Char/Min. 200 Char/Sec. 90 Char/Sec.	Delay Line	1000	40.4 to 404	Mag. Tape Printer Printer Printer Tape to Card Mag. Tape to Paper Transrecorder	128000 Char/Sec. 10 InSec. 10 Char/Sec. 600 Lines/Min. 120 Cards/Min. - 50 Char/Sec. 90 Char/Sec.	GP	1
	II	H	G	949	3030	Mag. Tape Keyboard Card to Tape Paper to Mag. Tape Verifier	100 In/Sec. Manual 240 Cards/Min. 200 Char/Sec.	Mag. Core	2000-10000	20	Mag. Tape Uniprinter Hi-Speed Printer Tape to Card Mag. to Paper Tape	- 10 Char/Sec. 600 Lines/Min. 120 Cards/Min. 90 Char/Sec.	GP	1
	60	D	A	138	-	Card Punch	75 Cards/Sec.	Vacuum Tube	6	-	Card Punch	-	B; S	3
	120	D	B	130	-	Card Punch	75 Cards/Sec.	Vacuum Tube	12	-	Card Punch	-	B; S	3
	File	EF	B-E	1000 Sq. Ft.	-	Card Punch Keyboard Paper Tape Mag. Tape	- - - -	Large Capacity	1800000	Char. Random	Card Punch Keyboard Paper Tape Mag. Tape	- - - -	File Sort Complete	-
	Scientific 110PA			(1000 to 2000)25,000-50,000(946 Sq.Ft.)	486	Mag. Tape Tape Reader Card Repdr.	2130 Words/Sec. WO Fr./Sec. 120 Cards/Min.	Mag. Core Mag. Drum	4096 16304	8 17500	Mag. Tape Printer Punch Reproducer Flexowriter	2130 Words/Sec. 600 Lines/Min. 60 Frames/Sec. 120 Cards/Min. Monitor	S	2

CB - Commercial Business
S - Scientific, Engineering
GP - General Purpose
CRT - Cathode Ray Tube
DDA - Digital Differential Analyzer

PURCHASE DOLLARS

A - Under 25,000
B - 25,000 to 50,000
C - 50,000 to 75,000
D - 75,000 to 100,000
E - 100,000 to 150,000
F - 150,000 to 500,000
G - 500,000 to 1,000,000
H - 1,000,000 and over

MONTHLY RENTAL DOLLARS

A - Under 1,000
B - 1,000 to 2,000
C - 2,000 to 3,000
D - 3,000 to 4,000
E - 4,000 to 5,000
F - 5,000 to 10,000
G - 10,000 and over

Report on Assignment 7

Engineering, Maintenance and Operating Benefits to be Derived From Increased Joint Use of Railway Facilities

Collaborating with Committees 11, 14, and 20

J. W. Barriger (chairman, subcommittee), C. H. Blackman, C. P. Blair, I. C. Brewer, R. M. Champion, Jr., B. Chappell, H. B. Christianson, Jr., J. E. Inman, H. P. Morgan, J. R. Nutter, F. J. Richter, H. L. Woldridge.

This is a progress report submitted as information.

The field of "joint" railway facilities is almost unlimited and therein lies one of the principal hopes for elimination of waste now inherent in railway transportation. The thousands of joint-facility contracts in effect offer good testimony to the practicability and economic feasibility of intensifying such joint usage, with resultant savings to be realized through abandonment of obsolete duplicating facilities as well as services in many instances.

"Joint facilities" need not be confined to a stretch of track or a particular station but can encompass the entire railroad plant and the personnel required in administration, maintenance or operation. They may include the "pooling" of services, both freight and passenger, to the ultimate economic advantage of the participating carriers and the communities served.

The great problem in working out a joint-facility arrangement is how to divide the benefits and assess the costs. Frequently, there are situations that involve competitive traffic, and there is a natural unwillingness to surrender an advantage, which can be readily visualized from experience; this is a real problem but is not insurmountable when other factors are properly weighed. Present economic conditions require the full ingenuity of the railroad official family in consummating joint-facility arrangements, one of the few steps available today for increasing railway income.

Although there are a great number of joint-facility agreements, they are generally confined to main tracks, stations, yards and terminals, whereas comparatively little has been accomplished in the field of coordinated services, either passenger or freight. The "duplicating" services requiring maintenance of elaborate separate facilities, ostensibly for the purpose of providing competition, represent a burden on railroad operating costs that is difficult to justify under existing conditions, especially in the light of subsidization of the railway competitors in the field of transportation—water, highway, and air. The railroads must, therefore, take full advantage of opportunities to reduce their costs of "conducting transportation" for passengers and goods; intensified use of the more favorable routes and preferred terminal locations presents an opportunity for the railroads to better cope with the ever increasing costs of operations.

It is the recommendation of your committee that the railroads thoroughly explore the possibilities of new joint-facility projects. Such investigations should embrace all phases of railroad operations and facilities. For convenient reference the following classes of facilities, personnel and services are listed, and there are perhaps others which are peculiar to certain railroads:

Road trackage
Classification yards
Delivery yards
Other freight terminals

Passenger terminals
Major bridges—drawbridges, etc.
Car shops
Locomotive shops
Pole lines
Radio stations and networks
Teletype systems and other communications
Microwave systems
Power stations
Power transmission lines
Work equipment
Major maintenance of way machinery
Office buildings
Icing stations
Stock handling stations
Outlying traffic agencies
Station agencies
Billing bureaus
Data-processing operating centers
Locomotive fueling stations
Marine operations
Administration services
M. W. machinery shops (including highway vehicles)
Research centers
Seasonal utilization of locomotives and cars
Reclamation shops
Purchases and stores
Various accounting bureaus
LCL truck operations
Ore and coal docks
Highway truck operations
Inspection organizations
Real estate management
Blueprinting and photography services
Bridge and building design, and engineering
Car and locomotive design, and engineering
Advertising, publicity and company magazines
Welding operations
Timber and tie plants
Track scales
Loss and damage
Claims bureaus
Probability of utilizing railway trackage and station facilities on an integrated basis for providing mass transportation in the larger communities

The benefits which may be anticipated from joint facilities will include:

1. Reduction in every phase of railway operating expenses for administration, maintenance and operation of facilities deemed unnecessary and burdensome.

2. Reduction in taxes for property abandoned.
3. Benefits from sale or lease of property and improvements no longer required for railroad purposes.
4. In many cases valuable property may be made available for industrial development on a basis that will provide new freight traffic for rail movement.
5. Will provide rail and other track materials that can be utilized to economic advantage for other main, branch, yard, or industrial tracks.
6. The probability of better service by the addition of modern facilities and through the improvement of maintenance standards made possible by the increased use of remaining facilities.
7. The possibility of more frequent freight and passenger schedules between major communities, to the ultimate competitive advantage of the railroad industry.

Perhaps of greatest importance to the railroad industry is the possibility of pooling services between major points in the interest of reducing operating expenses. This is most apparent in the case of passenger service where the utilization is far below the availability of service, but is also applicable to freight service in many instances. One example of service pooling is the passenger operations between the Twin Cities and Duluth, Minn. Such arrangement can substantially reduce the cost of rendering a higher quality of service over the "pool route", and this same idea can be effectively extended to freight services. In many instances, especially where unprofitable branch lines are involved, amalgamated services will produce substantial benefits by permitting abandonment of excess trackage—and with the far-flung highway system covering nearly every section of the country, such abandonment will not deprive local communities of service which they require.

We cannot undertake in this report to prescribe the terms and conditions of joint-facility contracts because of so many variables being involved, but there are innumerable precedents established which will serve as a guide for negotiating purposes, so we commend to the AREA and railway officers in general the task of exploring the possibilities of the engineering, maintenance, and operating benefits to be derived from increased joint use of railway facilities.

Reference is also made to the address of the subcommittee chairman on this subject, beginning on page 1151 of Vol. 59, AREA Proceedings for 1958.

Report on Assignment 8

Innovations in Railway Operations

A. L. Sams (chairman, subcommittee), Herbert Ashton, J. W. Barriger, W. R. Catching, Jr., H. B. Christianson, Jr., W. E. Quinn, F. J. Richter, L. K. Sillcox, C. W. Sooby, D. K. Van Ingen, L. E. Ward.

This is a progress report, presented as information.

Innovation—the process of change—is a constant process in the operation of a railroad. The alternative to change is decay, because the forces of nature and our environment dictate that we cannot remain unchanged. The rate at which innovations are adopted is one measure of our progress.

From the beginning of history, change has been an important factor in human affairs. It is the outstanding characteristic of our civilization today. The period during and following World War II will be recorded as the most dynamic in history, for this

has been the era of invention and development. One of the foremost developments has been the substitution of the machine for manual labor in performing the operations of many industries. In many respects the machine is superior to the human in the performance of these operations. It is more economical and more powerful; it is less inclined to aberration; it can work under extreme temperature ranges. For these and other reasons, the use of mechanical devices has been widespread.

Mechanization and automation have occurred in the railroad industry also. Labor-saving equipment has taken out much of the drudgery and reduced the cost of many maintenance of way operations. New kinds of signaling systems are expediting the movement of trains with a smaller force of operators. The use of radio and other communication devices is increasing the efficiency of yards and terminals. More recently, the introduction of electronic data-processing machinery has supplanted many of the manual functions in statistical bureaus and accounting departments. The railroads can point with pride to these achievements of the past decade.

On the other hand, it should be noted that nearly all of the recent innovations on railroads have been developed externally and adopted by the railroads. Instead of pursuing research and development independently, the railroads must rely on their customers, their competitors and, principally, their suppliers for new ideas. The railroads cannot hope, or afford, to do as much research work to develop new materials and devices as their suppliers, who have a broader market and a better chance to recover the cost of research, plus a profit. The railroads should, however, work closely with their supply specialists to let them know their needs, make suggestions and appraise the benefits to be derived from the new products.

Another significant observation that should be made at this time relates to the future need for rail transportation. No system has yet been devised that can provide mass transportation more efficiently and more economically than a railroad. While the airplane may be faster, the highway vehicle more flexible, and the pipeline more economical for transporting specific commodities under specific conditions, the railroad offers a combination of these characteristics. Furthermore, another characteristic of increasing importance is the greater adaptability of the railroad to automation.

The purpose of this study is to stimulate thinking along the lines of innovations in railway procedures by directing attention to some of the problems now facing us. A few suggestions are included in this report. Additional ideas are requested from other members for inclusion in further reports on this subject.

Specific Suggestions

One of the steps in engineering planning is the showing on plans by appropriate colors proposed new construction and facilities to be removed. Usually one is shown by red lines and the other by yellow lines. Several copies of the prints are usually required, and a considerable amount of work is involved in their preparation. A desirable improvement in their procedure would be effected by a simple blue printing process which would print the desired color lines. This would be accomplished by drawing the lines on the original tracing with substances which react to light, and the sensitized printing paper to produce the desired colors. The substances used must be easily removed without damaging the original tracing.

Train movements are expedited by good communications between the dispatcher and the train and engine crews. Two-way radio is now being used for this purpose, but is not considered entirely suitable for transmitting train orders. If radio-operated teleprinter facilities were available for transcribing train orders direct to the locomotive

and caboose, the intermediate operator could be abolished and greater efficiency would result. It would be necessary to provide both sending and receiving equipment on the locomotives and cabooses to insure receipt and understanding of the orders.

One of the problems in relaying rail in track is the positioning of the tie plates under the new rail. A suggested solution is to place the tie plates, using a template against the opposite rail, and hold them in position with staples until the rail is spiked.

Diesel locomotives require an adequate supply of water for cooling purpose and for the generation of steam to heat passenger cars. The presence of scale-forming minerals is objectionable, and water containing these minerals must be softened. The usual procedure is to establish resin-type water-softening plants at locations where the locomotives are supplied with water. These plants must be regenerated periodically with salt. A new method of removing or rendering harmless the objectionable minerals is desired, one which will not require the frequent attention necessary with the present type.

Great progress has been made in the development and use of plastics during the recent years. There are many potential applications of plastics to the railroad industry. Plastic pipes and conduits may prove to be satisfactory substitute for metal pipes in areas where corrosion or electrolysis is a problem. Plastic coatings can be used to prevent weathering of exposed metal parts. Some consideration has already been given to the use of plastic material as a substitute for cross ties. Structural uses of epoxy adhesives in railroad work has been submitted as a research project for the AAR. Such adhesives might be considered for bonding tie plates to ties, providing a pad and a sealant. They may be cast or molded to form a substitute for the cut spike, used as a chemical sealant for joining rail ends in place of conventional rail joints, or used instead of welding. Undoubtedly many more applications will be discovered as plastics are improved and developed.

High-speed electronic computers and data-processing machines are now in use on several railroads to perform accounting and statistical work. Study is now being given to engineering and other problems to which these machines can be applied. One of the assignments of Committee 16 (see report on assignment 7) is to suggest new applications of electronic computers. As we learn more about the characteristics of the machines, many new uses will present themselves. A possible use that has been presented is a central accounting system for all railroads to record car movements and determine per diem charges. Interchange reports would be prepared on sensitized forms and forwarded to the headquarters of the system. The central system could act as a clearing house for per diem charges, debiting or crediting each of the member roads monthly. Another application of data-processing equipment on an individual railroad is as a central filing and recording system. All necessary statistics would be transmitted to and stored by the central unit. From these records all accounting and statistical functions would be performed by the machine. Correspondence files, engineering drawings and similar documents would be recorded on microfilm and the microfilm inserted in punch cards for filing. Closed circuit television with receiving units located at strategic points would provide a means of viewing the documents, and teleprinter service would quickly furnish the desired information in printed form.

The known uses of radioactive materials suggest that these may have applications to railroad work. One such application would be radioactive signaling devices to replace the present systems of signaling. Another application might be equipment for identifying cars automatically.

The operation of freight yards and terminals offers many opportunities for innova-

tions to reduce costs and to improve the efficiency and safety of the work. Much progress has been made along these lines in recent years, particularly in the operation of retarder classification yards. One possible improvement in this area is the use of an endless chain arrangement to move cars from the receiving yard to the crest of the hump. This would eliminate the need for the humping locomotive and would provide better control over the humping operation. Another suggestion to perform the humping operation without using a hump locomotive is to install a series of hydraulic rams between the receiving yard and crest of hump to push the cut of cars. In either case some provision would be necessary to do the trimming in the classification yard. This could be accomplished by using a remote-controlled robot locomotive. Still a third suggestion to eliminate the hump locomotive is the robot hump engine, operated by the conductor in the hump office by remote control equipment. In the latter arrangement, the robot hump locomotive could be used to trim and perform other operations. Also, in hump classification yards the use of retarders instead of skates would reduce the cost and improve operating efficiency.

Comment was made earlier in this report on the adaptability of the railroads to automation. The rails that carry the trains also guide them and can be used to transmit instructions to them. A railroad is an economical transportation system because a small crew of men is adequate to control a large train. The disadvantage of this system is the delay caused by the accumulation of small units into trainload lots. Dispatchment of individual carload lots would eliminate this objectionable delay. Small-lot dispatchment is economical and practical only if each car contains a power unit for locomotion and if the movement can be made without a crew. Automatic operation without a crew can be accomplished by a tape on the car to define the position of each switch on the route from origin to destination. Devices must be installed to insure proper separation of cars or trains to provide adequate braking distance, and to stop the forward progress at destination.

To eliminate the excessive costs and delays associated with our present system of terminal operations, it may be possible to change our practices and do away with most of our passenger and freight terminals. Our passengers would meet the trains by car, and shippers would be served door to door by piggy back.

The maintenance of our rolling stock is a fertile area for the institution of innovations. Freight cars can be built to run from shopping to shopping without attention to draft gears, brakes, trucks, bearings, wheels, etc., but it will require provision for the same and very careful policing when cars are released from shops for such a term of service (5 to 7 years). Supplementary inspections, as nearly automatic and frequent as economically possible, must also be made. Electronic equipment for locating internal defects must be installed at terminals and other strategic points. To reduce the damage to equipment and lading and the delays in transit caused by derailments, automatic devices to detect broken flanges, loose and broken wheels and hot boxes should be provided at frequent intervals along the main tracks.

The widespread adoption of trailer-on-flat-car operation has stimulated thinking on other methods of packaging commodities for transportation. The handling of mail and express shipments by piggy back in passenger trains could reduce cost and expedite this operation at passenger terminals. The use of pallets for the mechanized handling of LCL freight, mail, express and baggage is also suggested.

Improvement in freight train operation might be effected by spacing diesel units throughout the train instead of placing all units at the head end. The operation of all units could be synchronized and controlled by radio from the leading unit. The spacing

might be so arranged that at important intermediate terminals and junction points a unit would be placed with set-out cars and used to make the switch.

The most costly item of material in maintenance of way is cross ties. Undoubtedly this cost could be reduced by better inspection methods to supplement visual inspection. This might be accomplished by inducing vibrations in the tie with a portable oscillator, interpreting the results in terms of the physical condition and remaining life of the tie.

Report on Assignment 9

Economics and Methods of Utilizing Railway Property, Rights-of-way, and Facilities to Develop or Increase Secondary Sources of Railway Revenue

F. J. Corporon (chairman, subcommittee), J. W. Bolstad, Q. K. Baker, I. C. Brewer, D. E. Brunn, B. Chappell, F. B. Peter, H. F. Schryver, C. E. Stryker, J. E. Teal.

This is a final report, presented as information.

A compilation of ideas submitted as applicable to the scope of the assignment is presented herein for consideration by those who are interested in the possibilities of enhancing economic stability for their railroad by developing or increasing secondary sources of revenue.

The ideas are merely listed without detailed discussion thereof. As the railroads differ from each other, the economies to be realized and the methods of application of the various ideas must be analyzed and studied in the light of the peculiarities of the particular railroad that might be interested.

The listings are grouped under general classifications as a convenience to continuity of thought:

1. *Executive, Financial and Legal*
   a. Joint use of legal facilities.
   b. Consulting work for foreign railroads and governments.
   c. Contract operation of other railroads, terminal companies, industrial railroads, real estate organizations, etc.
2. *Real Estate and Taxation*
   a. Rent unused buildings and terminal property to others.
   b. Dispose of excess width, on line, of right-of-way where possible.
   c. Make use of right-of-way beyond normal width.
   d. Make geologic investigation for presence of underlying oil or minerals.
   e. Realize full market value of right-of-way cut off from further use by public roadways on right-of-way.
   f. Sell or lease air rights.
   g. Lease right-of-way for pipe lines, power lines, airway beacons, radio and guidance systems, automobile parking, etc.
   h. Assemble, develop and sell real estate as industrial districts served by all phases of transportation.
3. *Personnel*
   a. Perform medical examinations for other railroads, terminal companies and industries.

b. Qualify employees for other railroads, terminal companies and industries.
c. Recruit and train technical personnel and specialists for other railroads, terminal companies and industries.
d. Joint use of consultants and technical specialists.
e. Provide consultants and technical specialists on a fee basis for other railroads, industries and governments.

4. Public Relations

a. Sell souvenirs, timetables, books, old equipment, etc., to railfan organizations and the public.
b. Provide public inspection of outstanding railroad operating interests on a paid admission basis.
c. Enlarge scope of employee magazines for subscription and news-stand sale to the public.

5. Research and Development

a. Joint use of research facilities.
b. Make railroad research facilities available to others on a rental, fee or contract basis.

6. Accounting

a. Joint use of electronic computers.
b. Perform accounting for other railroads, car companys, etc.
c. Rental of time on computing facilities at night or off hours.

7. Traffic

a. Joint tariff files for other railroads, terminal companies and private car companies.
b. Handle traffic cases and matters for other railroads and terminal companies on a fee basis.
c. Use passenger sales facilities, so qualified, as travel agencies for all forms of connecting transportation.
d. Operate traffic and rate education courses on a fee basis.

8. Operating

a. Use of employees to handle part-time jobs on a contract basis.
b. Rental of unused tracks to other companies for storage of cars.
c. Consolidated operation of piggy back terminals on a fee basis.
d. Operate central yard facilities for other railroads, including freight terminals, port facilities, marine equipment, etc., on a contract or fee basis.
e. Provide operating facilities for fan clubs, historical railroad clubs, etc.
f. Provide point to point movement of automobiles and auto passengers on a per car basis.

9. Purchasing, stores and insurance

a. Joint store houses on a fee basis.
b. Sell old records for waste paper.
c. Construct and operate warehouses, market terminals, etc., for other railroads and industries.

d. Sell material or perform service in treating plants, reclamation plants, frog and welding plants, quarries and gravel pits to others.
e. Operate centralized scrap reclamation and sales yards for use of railroads on a fee basis.

10. Mechanical

a. Use shop facilities to perform work for smaller railroads, industries and private car lines.
b. Lease of cars for storage purposes, temporary housing, etc.
c. Off-season rental of locomotives and car equipment to other railroads and industries.
d. Perform wood and metal work for others in company shops.

11. Engineering

a. Perform engineering for railroads and others on a consulting basis.
b. Furnish consulting engineering service for cities and towns on line
c. Furnish water supply service for smaller communities.

12. Bridges and Roadway

a. Joint use of bridges.
b. Use bridges for advertising.
c. Reclaim bridge timbers and sell as blocking.
d. Pulverize old ties, timber, etc., for animal bedding, etc.
e. Rent off-season or excess equipment to other railroads or industries.
f. Larger railroads to perform maintenance of way and bridge work for smaller railroads and other industries.
g. Lease advertising space on trucks.
h. Conversion of bridges to rail–highway use on a toll basis.
i. Lease billboard space on right-of-way.

13. Communications and Signals

a. Sell obsolete relays, communication equipment and material to hobbyists and others.
b. Perform circuit design and layout work for others.
c. Lease pole line and facility space to telephone and power companies.
d. Operate consolidated PBX and communications centers for other railroads.
e. Off-peak rental of teletype circuits

14. Miscellaneous

a. Purchase and rental of unloading and freight-handling equipment to industries.
b. Operation of automobile and truck rental organizations at terminals.
c. Construct and lease operation of motels, cabins, etc., in resort or other suitable areas under real estate companies

Report on Assignment 11

Review of Developments in New Methods and Modes of Transport

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Your committee submits the following as the first in a series of reports on this assignment.

The Use of Pipelines for the Long-Distance Transportation of Solids

Introduction

The solids-carrying pipeline is an ingenious form of transportation which has only recently begun to attract attention as a possible competitor of the more established carriers. Although the physical principles involved and instances of their application to short-distance pipelines are not unfamiliar to most railway engineers, the construction of lines for long-distance transportation is an innovation which merits special attention. Railroad engineers should know—because railroad management *must* know—the extent to which such lines might be competitive under any given set of circumstances.

Concurrent with this study by Committee 16, Committee 13—Water, Oil and Sanitation Services, has also been investigating this development. It is natural that both groups should study the same problem. Committee 13 is investigating the problem primarily from the standpoint of the techniques involved, whereas this particular report places greatest emphasis upon the origin of the development and its economic character as a mode of transportation of certain types of commodities.

Two major solids lines are already in operation in this country, one handling freight which would otherwise have moved by truck, the other handling freight which *was* moving by rail. The first of these is a 6-in line, 72 miles long, which moves 250,000 tons of gilsonite annually from Bonanza, Utah, to Gilsonite, Colo.[1] The gilsonite, which has a density 1.05 times that of water, is crushed into particles whose top size is 8-mesh. These are held in suspension in a water slurry which is almost 45 percent solids by weight. A 300-hp reciprocating pump discharges 325 gal of slurry per minute into the line, the power requirements being almost identical with those for an equal volume of clear water. (It is estimated that the installation of an intermediate booster pump could increase the capacity of the line to more than 600,000 tons annually.) The line has been in successful operation since April 1957, and is producing transportation savings estimated at $4 per ton over an alternative 200-mile haul by highway.

The other installation is the Consolidation Coal Company's 10-in coal slurry line which extends 108 miles from Georgetown to Eastlake, Ohio.[2] This line can handle 1,250,000 tons of coal per year, and according to recent estimates should save some $0.75 per ton over existing rail freight charges. The coal particles are 14-mesh and under, and the water slurry in which they are carried contains nearly 50 percent coal

[1] See Robert K. Bond, "Engineering Design, Testing, and Operation of the Gilsonite Solids Pipe Line," paper presented at the ASME Petroleum Engineering Conference, Tulsa, Okla., September 1957. See also Elton Sterrett, "American Gilsonite Pipeline Successfully Handles Slurries," *Pipe Line News*, August 5, 1957, pp. 78–79.

[2] See Clarence A. Dauber, "Pipeline Coal Transportation," *Coal Age*, April 1957.

by weight. The line has three pumping stations, each equipped with three 450-hp reciprocating pumps, any two of which can handle the load together. Extensive pilot plant studies were made to determine hydraulic characteristics before the line was built, but considerable difficulty was encountered in getting the full-scale terminal equipment into satisfactory operation. After many months of testing, the line began regular operations in April 1958.

The Nature of Solids Pipelines

Basically these lines are very similar to conventional fluid pipelines handling water. The difference in this case is that the moving stream of water carries a large number of small solid particles in suspension, the designers having made use of the fact that above a certain minimum velocity these particles will not settle out. Physically, this is the same phenomenon that one observes in the sediment-carrying ability of an open stream.

The introduction of solid particles into the fluid stream makes necessary a number of special design features not common to conventional pipelines. The most important of these are the preparation and recovery plants required at the ends of the line. At the input end the material to be piped must be crushed and screened to reduce its particle size to an acceptable maximum. The particles must then be mixed with water in the proper proportion for pumping. If the preparation plant does not operate continuously but the pipeline does, the prepared slurry must be stored (and continuously agitated) in tanks or ponds. At the discharge end of the line, equally complicated equipment may be required to dewater and dry the solid material so it can be put to its desired use. (The drying plant for the coal line previously mentioned cost $2,000,000 to install.)

As might be expected, conventional centrifugal pumps are not suitable for handling slurries containing heavy concentrations of solid materials because of clogging of the vanes and abrasion of the volutes and impeller blades. The use of pumps with semi-open impellers and a reduced number of vanes can overcome some of the problems involved, but only at the cost of volumetric efficiency. Reciprocating pumps are more satisfactory, and in general more readily adaptable to solids-line service. Both the gilsonite and the coal lines use reciprocating pumps, those for the coal line having been designed originally for mud-jacking operations.

These lines present other problems, too. Extra pipe-wall thickness is usually required to provide for the abrasion of the solid particles on the bottom half of the pipe in particular. Maximum curvature must be limited to prevent excessive erosion of the side walls. Maximum gradients must be limited as well, because the particles have a tendency to roll backwards on a steep ascent. (In the case of the coal line, experiments showed that this maximum should be no more than 18 percent.) Finally, some precautions are necessary to prevent plugging of the line; these may be shutoff valves, standby water reservoirs at the pumping stations, or special provisions for back-flushing of the line.

The Advantages of Solids Pipelines

In general, solids pipelines do not possess any advantages over other forms of transportation which are not also enjoyed by straight fluids pipelines. Some of these advantages, however, are quite significant.

One obvious advantage of a pipeline is that there are no moving vehicles to maintain. The extreme simplicity of the permanent way (the pipe) reduces maintenance requirements even further. In addition, the lack of discrete vehicles greatly simplifies

the problem of movement control, as compared, for instance, with railroads and highways. As a result, the total manpower required for operation is very small, a distinct advantage in an era of rising labor costs.

In pipelines the resistance to motion which must be overcome is quite low (though significantly not so low as in the case of railway transportation.) This, coupled with the lack of vehicle deadweight and the absence of empty return trips, means that power requirements are also low. Fluid pipelines enjoy a great advantage in this respect, for the ratio of net to gross tons to be moved is exactly 100 percent. Solids pipelines do not possess such a marked advantage, however, since the water portion of the slurry is in effect dead weight to move; but the 45 percent net-to-gross ratio of the gilsonite and the 50 percent ratio of the coal line still compare favorably to truck and rail operations where empty back-haul is involved.

Another advantage of pipelines is the much simplified right-of-way problem encountered in their location. Because the restrictions on grades and curvature are less severe, the costs of land and grading are generally much lower than would be the case for a railroad or a highway. While solids lines, as pointed out above, are more restricted than fluids lines, they share this advantage. They also share the advantage of light loadings, which greatly reduce the cost of any bridges or other supporting structures which may be required.

The Disadvantages of Solids Pipelines

At the same time, solids pipelines have some disadvantages which must be considered serious. The first and foremost of these is their ability to handle very limited types of traffic. To be transportable in a solids line, a material must be one that: (1) can be reduced to a small particle size and still retain its commercial value; (2) will not lose this commercial value because of a certain amount of abrasion; (3) will not be damaged by contact with water (or whatever transporting medium is in use); (4) can be economically dewatered or dried at the discharge end of the line, or can be used in slurry form without dewatering; (5) does not contain chemicals which will cause excessive corrosion of the interior of the pipe; and (6) will not segregate unduly so as to cause blockage of the line. Clearly, the number of materials which could meet all of these conditions is somewhat limited. Among those which might, however, are many which presently move by rail in large volumes.

The second disadvantage of solids pipelines is that they are relatively inflexible as to origin and destination. The equipment required both for slurry preparation at the initial terminal and for dewatering and drying at the discharge terminal will in most cases be both extensive and non-portable. Thus, unlike most fluids pipelines, it is not possible to add branches or extensions easily. The result is that a solids line is not likely to be economical except where the source of supply and the consuming market are both fixed geographically and certain to last for a long period of time.

A third consideration is that the first cost of a solids line per unit of annual capacity is higher for most usual situations than would be the case for highway or railway transportation. For the Ohio coal line, for instance, first costs (excluding research) were on the order of $0.08 per annual net ton-mile of capacity, while a single-track rail line used at or near capacity might have had a first cost well below $0.02 per annual net ton-mile of capacity. The question of how much capacity is needed in a given situation is the crucial one to ask; it most probably would not have been feasible to build a railway line to move only 1,250,000 tons of coal per year.

One other cost factor is important. As yet the physical characteristics of solids pipelines are only imperfectly understood. Thus, research costs are very high (more than $2,000,000 in the case of the coal line), which puts this form of transportation at a serious disadvantage. Some research on the subject is now underway, however, which together with the experience gained in existing lines may soon remove this disadvantage.

Discussion—Solids Pipelines vs Railroads

In situations where a limited amount of material is to be moved each year, solids pipelines can offer serious competition to the railroads. This presumes, of course, that the material to be moved is one which can meet the criteria set forth in the foregoing and that both the line origin and destination are fixed. Within these limitations, over-all pipeline costs are likely to be well below the fully allocated costs of rail transportation, particularly in a situation where no railroad yet exists. Where a parallel rail line does exist, however, fully allocated pipeline costs could well be higher than the marginal (i.e., out-of-pocket) cost of railroad movement.

The Ohio coal line, for instance, was designed for an over-all movement cost of about 1.5 cents per net ton-mile. Of this only 15 percent, or about 0.23 cents per net ton-mile represents out-of-pocket expense. It is certainly conceivable that the fully allocated rail costs might be as low as this 1.5 cents figure. (In this case the freight rate seems to have been well over 3 cents per net ton-mile).

Even with fully allocated rail costs of 2 cents, the out-of-pocket rail cost should have been less than 1.5 cents and perhaps as low as 1 cent per net ton-mile (that is, 50–75 percent of total costs). Thus, for an entirely new route a solids pipeline may have the edge; but where there is already a railroad the solids line may come out second best, *if* the railroad is permitted to set its rates at or near the marginal cost of its operations.

There is a third type of competitive situation which is also conceivable—that in which a solids line and a railroad have both existed previously and are competing for some new form of traffic. (The possibility that a pipeline could handle more than one type of solid material is technically quite feasible.) Under these circumstances each could price at marginal cost, and on that basis the pipeline would be by far the cheapest. This advantage would be due largely, of course, to the very small labor costs involved in operating the pipeline. It is important to notice that railroad operations are susceptible to much improvement in this respect, so that in the future these economic relationships may change.

The conclusions are somewhat obvious: if the railroads can reduce their out-of-pocket operating costs and if they are permitted to price their services on this basis when necessary, solids pipelines may not pose any serious competitive threat. The exception to this will be only in the case of new routes where the total traffic volumes are too low to justify railroad construction. Today, of course, railroad out-of-pocket costs are still quite high, and marginal pricing is frequently prohibited by the ICC; so the development of solids pipelines cannot be ignored. Only two such lines have been discussed in this report, one which carries gilsonite and one which carries coal, but other operative lines carry clay (9 miles) in Georgia and mill tailings (7½ miles) in Ontario. Research is already underway, moreover, to determine the adaptability of sand, limestone, and pelletized taconite to transport by solids pipeline.

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In addition to those already cited, the following references are of particular interest:

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Report of Committee 9—Highways

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P. D. TRACY
T. M. VANDERSTEMPEL
V. R. WALLING (E)
R. WESTCOTT

Committee

(E) Member Emeritus.

To The American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 246

2. Merits and economics of prefabricated types of highway–railway grade crossings.
   Progress statement, presented as information ..... page 246

3. Merits of various types of highway–railway grade crossing protection, collaborating with Signal Section, AAR.
   No report.

4. Recommended device to guard highway–railway crossing signs and signals from damage by vehicular traffic, collaborating with Signal Section AAR.
   Final report, submitted as information ..... page 247

8. Recommended protection at highway–railway grade crossings where one-way traffic on the highway crosses one or more tracks on the railway, collaborating with Signal Section, AAR.
   Final report, with plans and requisites submitted for adoption and publication in Manual ..... page 249

THE COMMITTEE ON HIGHWAYS,
C. I. HARTSELL, *Chairman.*

AREA Bulletin 546, November 1958.

Report on Assignment 1

Revision of Manual

J. M. Trissal (chairman, subcommittee), B. Blum, C. M. Carnahan, A. C. Cayou, H. B. Clarkson, R. Dejaiffe, A. D. Duffie, W. R. Dunn, E. R. Englert, J. T. Fitzpatrick, C. I. Hartsell, F. T. Miller, H. G. Morgan, D. D. Rosen, P. D. Tracy.

Your committee offers the following recommendation with respect to Chapter 9 of the Manual:

Page 9-2-1

RECOMMENDED USE OF HIGHWAY-RAILWAY GRADE CROSSING SIGNS

In the second column of the table, change the last sentence of paragraphs 2, 4, 5 and 6 to read as follows: "Reflecting medium may be reflector buttons or reflex-reflecting material."

This change is recommended in order to describe the materials properly and to make the wording conform with other descriptions.

Report on Assignment 2

Merits and Economics of Prefabricated Types of Highway-Railway Grade Crossings

R. E. Nottingham (chairman, subcommittee), F. B. Barker, R. B. Carrington, Jr., M. H. Corbyn, H. E. Dearing, Raymond Dejaiffe, T. L. Gibson, S. B. Gill, C. I. Hartsell, J. T. Hoelzer, W. H. Huffman, J. R. Latimer, J. F. Mark, R. W. Mauer, R. J. Pierce, R. E. Skinner, P. H. Slack, R. F. Spars, J. T. Ward, Raymond Westcott.

Your committee has secured data from several railroads covering the original cost and service results of various types of prefabricated materials for highway-railway grade crossings.

Accurate figures on maintenance costs are difficult to get, since in only a few cases are the installations considered a test. In most cases no attempt is made to separate the maintenance costs from other operating expenses.

Prefabricated treated timber slabs have been widely used by several railroads for the past 10 years. It now appears that a service life of about 15 to 20 years may be expected in the average installation where sound timber is used and good maintenance practices are followed.

Certain types of metal grating material used indicate a 20-year life expectance under favorable conditions, although the average life of a lighter weight metal grating material has been only about 8 years because of rust action and failure to keep dirt from clogging up the grating in the traffic lanes.

The rubber slab crossings under observation were first installed about 4 years ago. These include 10 main line and 9 industrial track installations. This type of crossing material is giving good service with practically no maintenance expense. Most of the rubber slab installations are subject to dense highway traffic, which caused failure in

other types of material used after a short period of time. The committee is watching these installations with interest.

Some long life records of 20 to 30 years have been made where concrete slabs were installed; however, most roads have found them unsuitable to present-day traffic conditions and are replacing them with other material.

Your committee is checking on several other matters related to the track structure and paving in highway–railway grade crossings, such as the use of rubber tie plate pads through crossings, the use of metal strips as flangeway guards, and the substitution of bituminous material for the filler blocks in flangeways. These items are not of such nature as to require a separate investigation. The conclusions of this committee will be presented after more information is available.

This report is offered as information. Your committee desires to study this assignment further, and recommends that the subject be continued.

Report on Assignment 4

Recommended Device to Guard Highway–Railway Crossing Signs and Signals from Damage by Vehicular Traffic

Collaborating with Signal Section, AAR

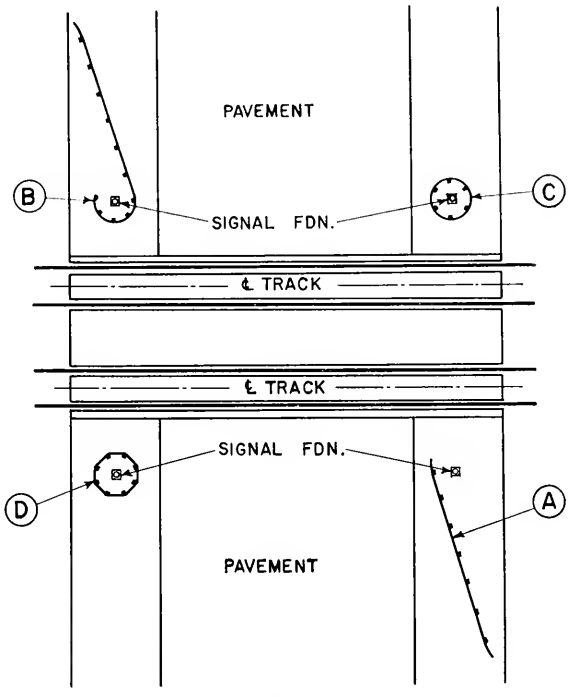
F. C. Cunningham (chairman, subcommittee), C. M. Carnahan, A. C. Cayou, H. B. Clarkson, J. R. Derieux, A. D. Duffie, W. R. Dunn, C. I. Hartsell, D. W. Hughes, Maro Johnson, J. A. Jorlett E. S. Miller, F. T. Miller, H. G. Morgan, R. E. Nottingham, Palmer H. Slack, V. R. Walling.

This assignment was undertaken because the AREA does not have a recommended device to protect grade crossing signs and signals from damage by vehicles. Highway traffic is constantly increasing, improved highways are being constructed and additional crossing signals provided. Unprotected signals are frequently severely damaged by vehicles.

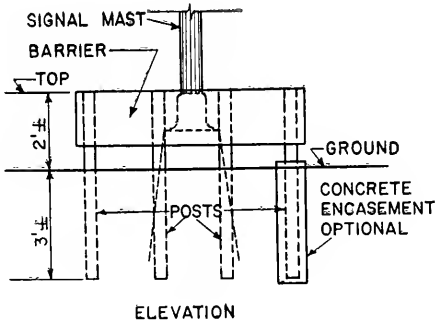
Your committee has investigated the present use of protective barriers. It was found that several different types have been constructed, all being centered about the signal mast, including (1) a large concrete pier, (2) a steam locomotive tire supported by pieces of rail, (3) a section of large diameter corrugated pipe supported by pieces of rail, (4) a barrier completely fabricated of rails, and (5) posts made of rails or wood. At least one state approves the use of the circular type of protection. While the above designs do afford protection, a vehicle striking the barrier directly may sustain some damage.

A later development is the guard-rail type barrier placed diagonally so that a vehicle striking it would ricochet and be diverted back to the traveled portion of street or highway, with minimum damage to the vehicle as well as protecting the signal. This design is in general use, particularly on federal highways, guarding open spaces, etc. Several states approve the use of this design to protect crossing signs and signals; in fact, at least one state requires such an installation where federal aid is involved in the cost of the signals.

The accompanying drawing (see next page) illustrates several of these devices. Your committee recommends that the report and drawing be accepted as information and that the subject be discontinued.



PLAN



ELEVATION

NOTE:
SOME VEHICLE BODIES PROJECT ONE FOOT BEYOND WHEELS. BARRIER TO BE LOCATED ACCORDINGLY AND OF SUFFICIENT SIZE FOR FULL PROTECTION.
POSTS MAY BE OF STEEL RAILS, WOOD OR STEEL MEMBERS.
(A) BARRIER OF CORRUGATED METAL OR WOOD.
(B) BARRIER OF CORRUGATED METAL.
(C) BARRIER OF CORRUGATED METAL OR LOCOMOTIVE TIRE.
(D) BARRIER OF STEEL RAILS.

TYPICAL BARRIERS TO PROTECT HIGHWAY-RAILWAY CROSSING SIGNALS FROM DAMAGE BY VEHICULAR TRAFFIC

Report on Assignment 8

Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway

Collaborating with Signal Section, AAR

D. W. Hughes (chairman, subcommittee), W. S. Autrey, G. B. Blatt, A. C. Cayou, S. B. Gill, P. J. Harnish, Wm. J. Hedley, W. H. Huffman, J. E. K. Krylow, J. F. Mark, H. L. Michael, E. S. Miller, R. J. Pierce, W. C. Pinschmidt, P. D. Tracy, T. M. Vanderstempel, Maro Johnson, V. R. Walling.

This is a final report, including recommendations submitted for adoption and publication in the Manual.

A progress report on this assignment, including a series of drawings showing signal aspects designed to provide basic minimum protection at highway–railway crossings for one-way highway traffic, was presented at the 1957 annual meeting and may be found in the Proceedings, Vol. 58, 1957, pages 444 to 456, incl.

These plans were subsequently revised as the result of a joint meeting of representatives of Committee 9 and of the Signal Section, AAR, on December 10, 1957, the revised plans having the approval of both Committee 9 and the Signal Section, so far as the signal aspects are concerned.

The revised plans, designated as Figs. 3A to 3J, incl., (excluding Fig. 3I), are presented herewith with the recommendation that they be adopted and published in the Manual as pages 9–3–6.1 to 9–3–6.9, incl., as a guide for various authorities in protecting highway–railway grade crossings where one-way traffic on the highway crosses one or more tracks on the railway. Local conditions, the laws of the various states, policies of the various highway authorities and the individual railways may require additional features not indicated on the plans.

In connection with the adoption of the aforementioned plans, your committee recommends revision of certain other material in Chapter 9, as presented below:

Page 9–3–1

RECOMMENDED USE OF HIGHWAY–RAILWAY GRADE CROSSING SIGNALS

In the second column of the table, at the end of the item reading "Cantilever flashing-light signal, as shown on pages 9–3–12 or 9–3–13", add the words "located as shown on pages 9–3–6.2, 9–3–6.3, 9–3–6.5, 9–3–6.6 and 9–3–6.7."

To the corresponding item in the third column add the following page numbers: 9–3–6.2, 9–3–6.3, 9–3–6.5, 9–3–6.6 and 9–3–6.7.

Pages 9–3–2 and 9–3–3

REQUISITES FOR HIGHWAY GRADE CROSSING SIGNALS

On page 9–3–2, add the following to the paragraph under Art. 1. Purpose: "for one-way or two-way traffic."

On the same page, add the following to the paragraph under Art. 2. Aspect: "except that back-to-back lamp units may not be required for one-way highway traffic."

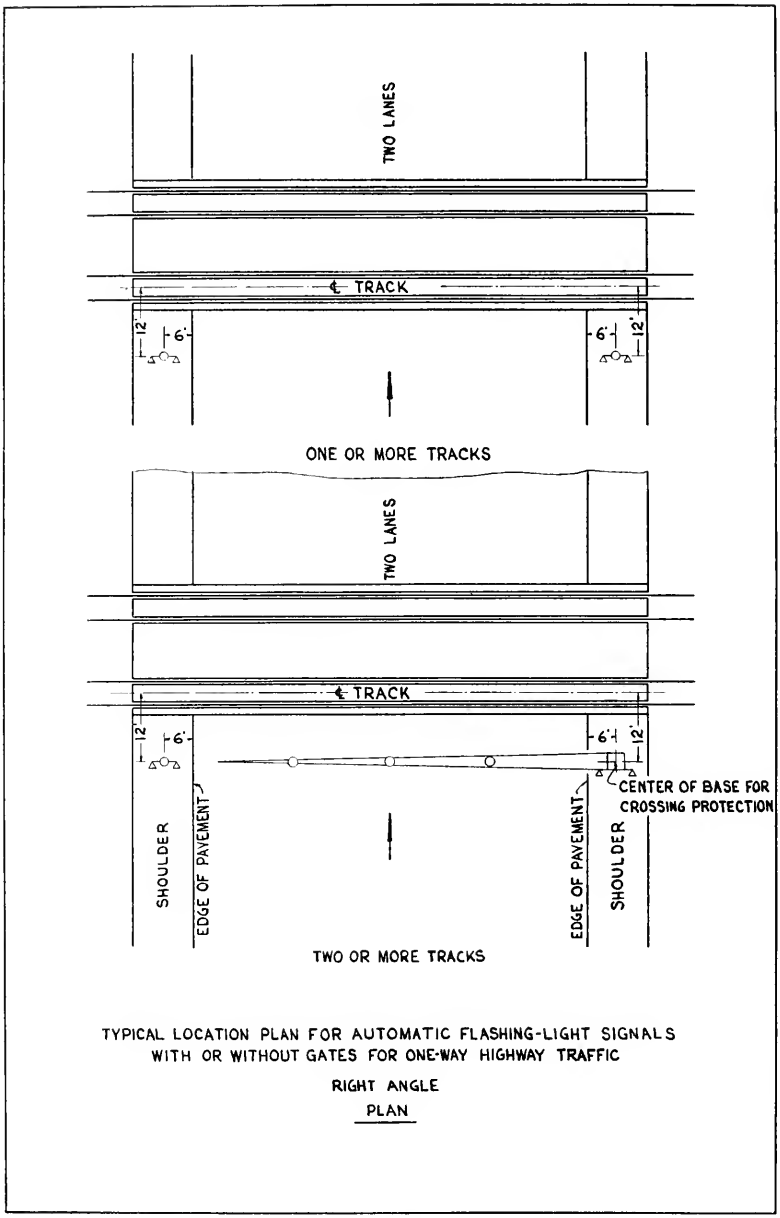
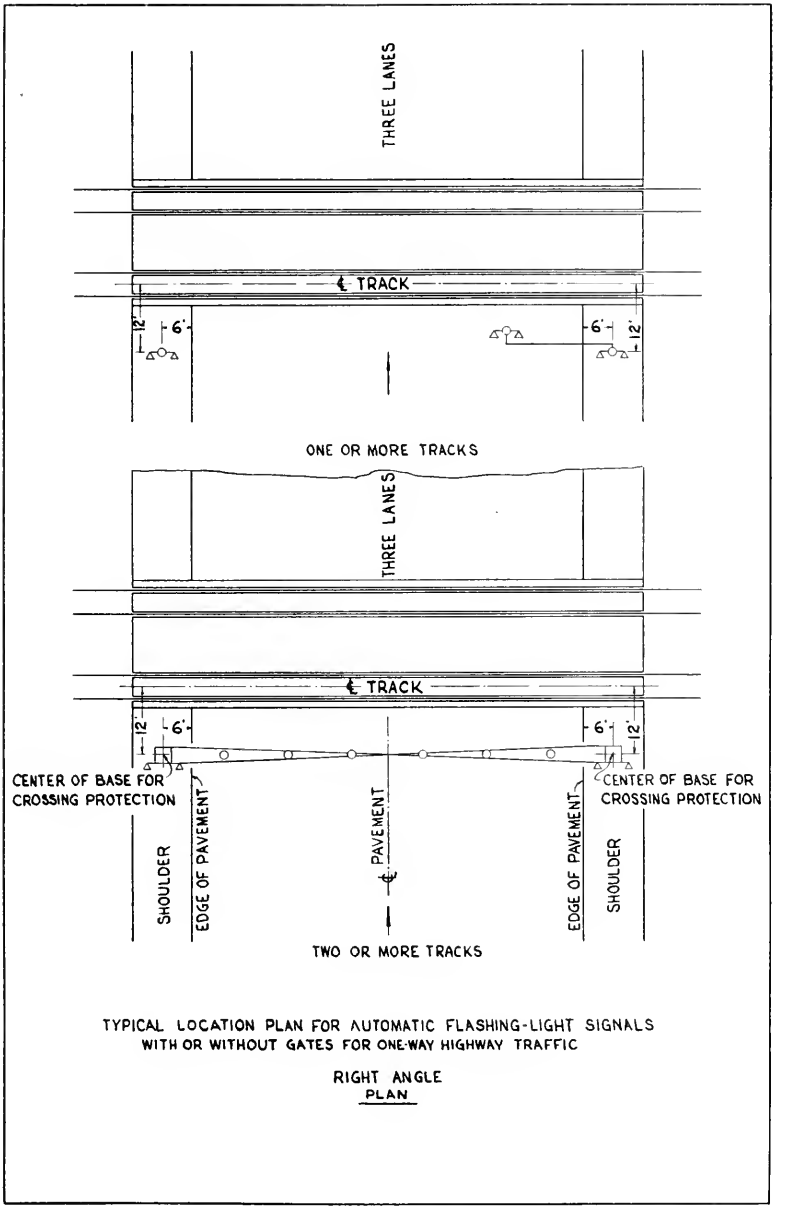

TWO LANES
℄ TRACK
12'
6'
6'
12'
ONE OR MORE TRACKS
TWO LANES
℄ TRACK
12'
6'
6'
12'
CENTER OF BASE FOR
CROSSING PROTECTION
SHOULDER
EDGE OF PAVEMENT
EDGE OF PAVEMENT
SHOULDER
TWO OR MORE TRACKS
TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS
WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC
RIGHT ANGLE
PLAN

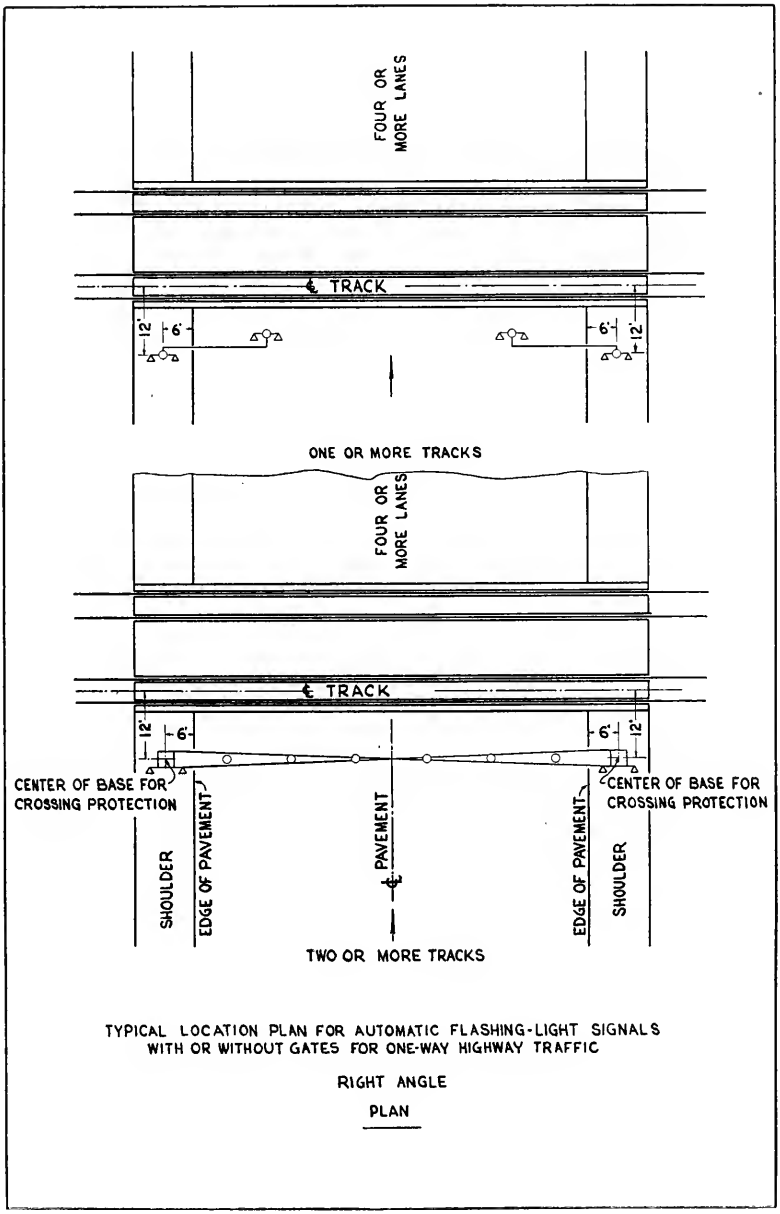
Fig. 3A.



TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC

RIGHT ANGLE
PLAN

Fig. 3B.

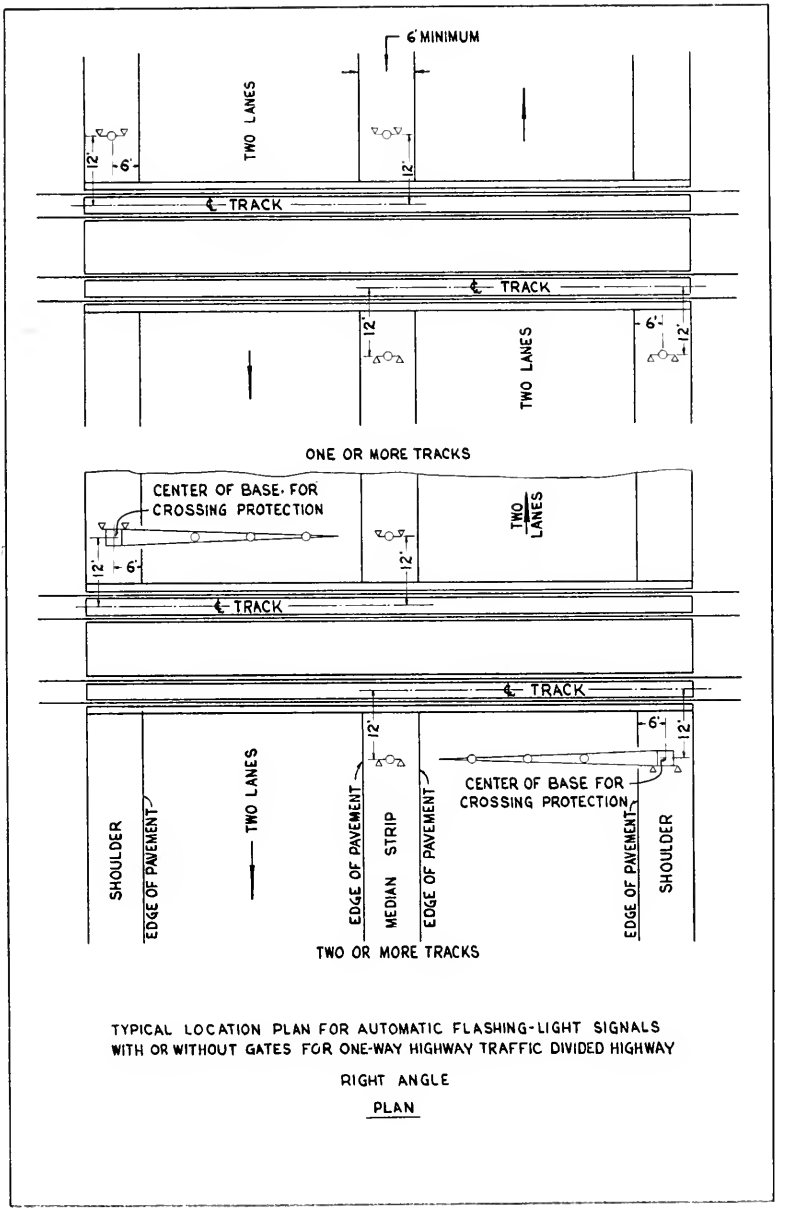


TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC

RIGHT ANGLE

PLAN

Fig. 3C.

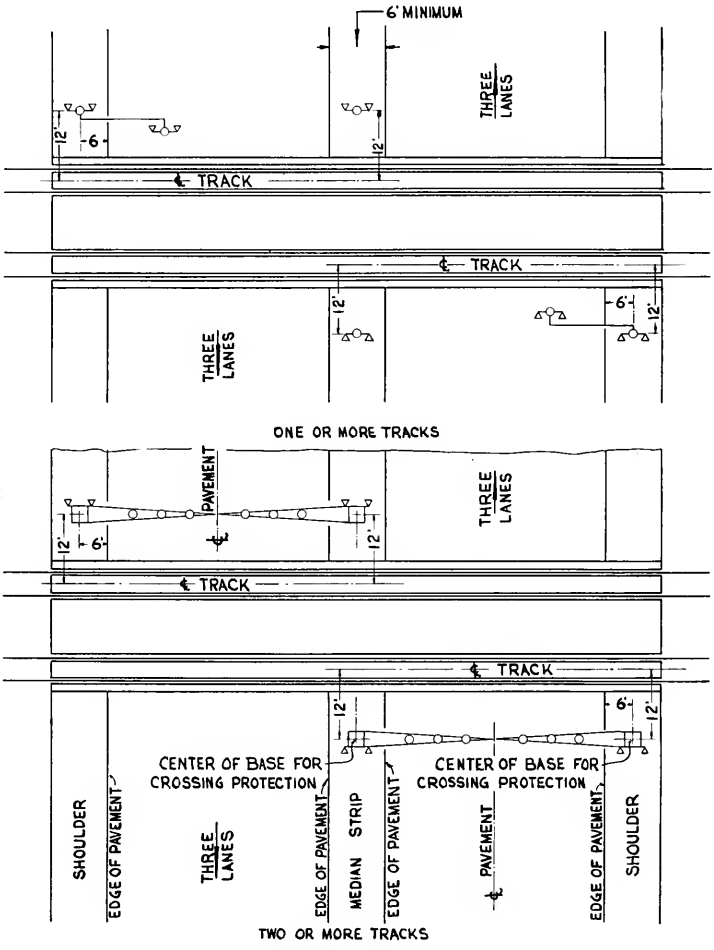


TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY

RIGHT ANGLE

PLAN

Fig. 3D.

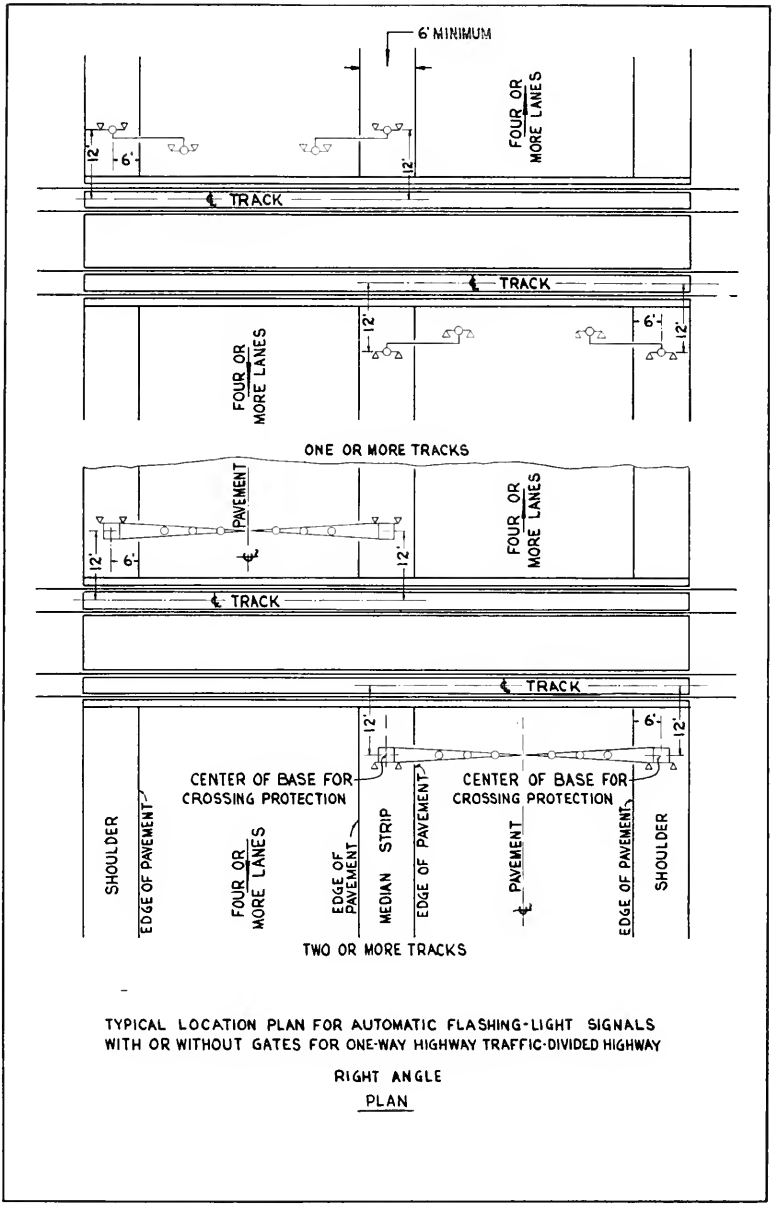


TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY

RIGHT ANGLE

PLAN

Fig. 3E.

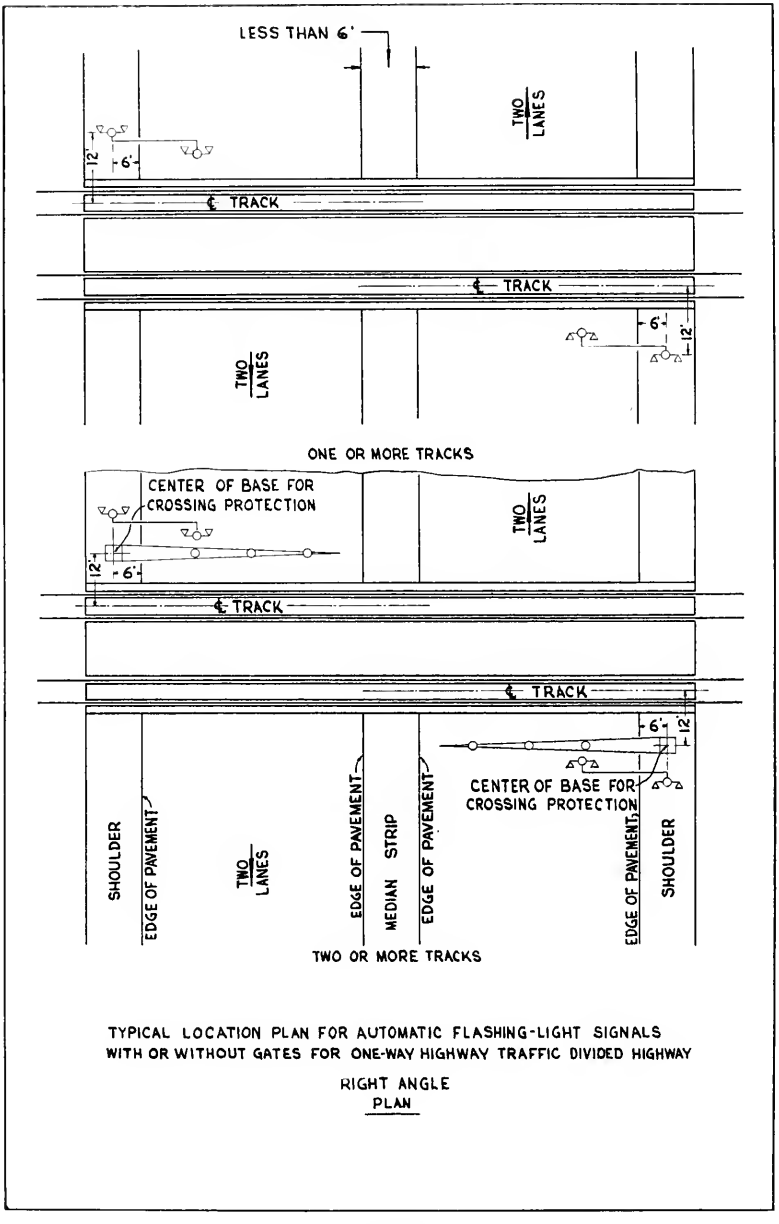


TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC-DIVIDED HIGHWAY

RIGHT ANGLE

PLAN

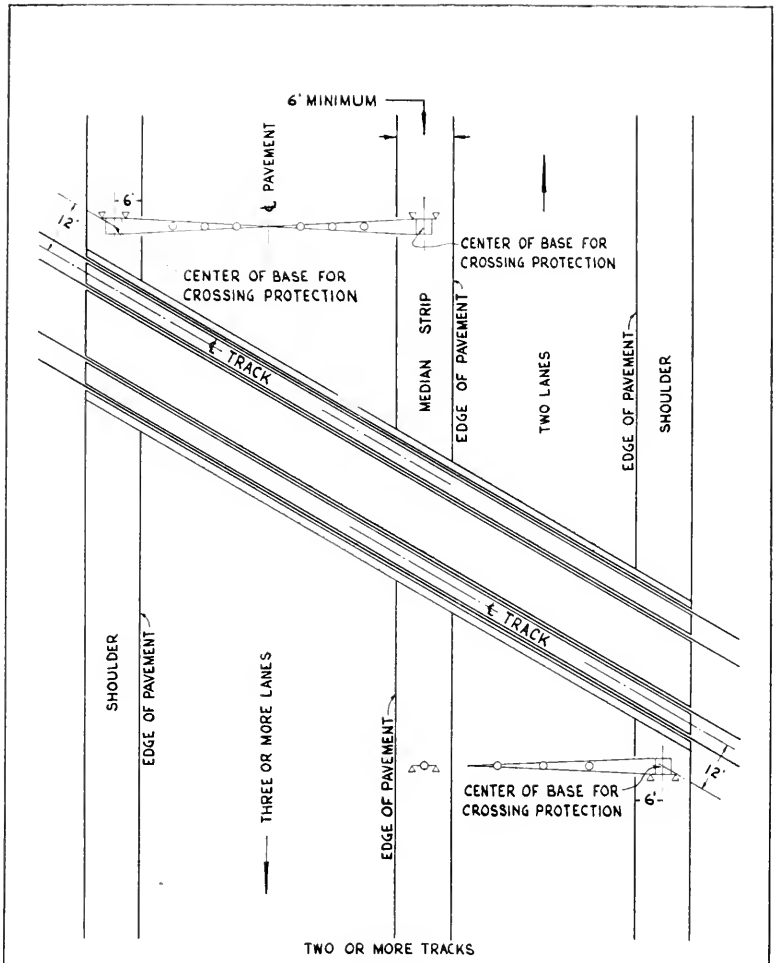
Fig. 3F.



TYPICAL LOCATION PLAN FOR AUTOMATIC FLASHING-LIGHT SIGNALS WITH OR WITHOUT GATES FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY

RIGHT ANGLE
PLAN

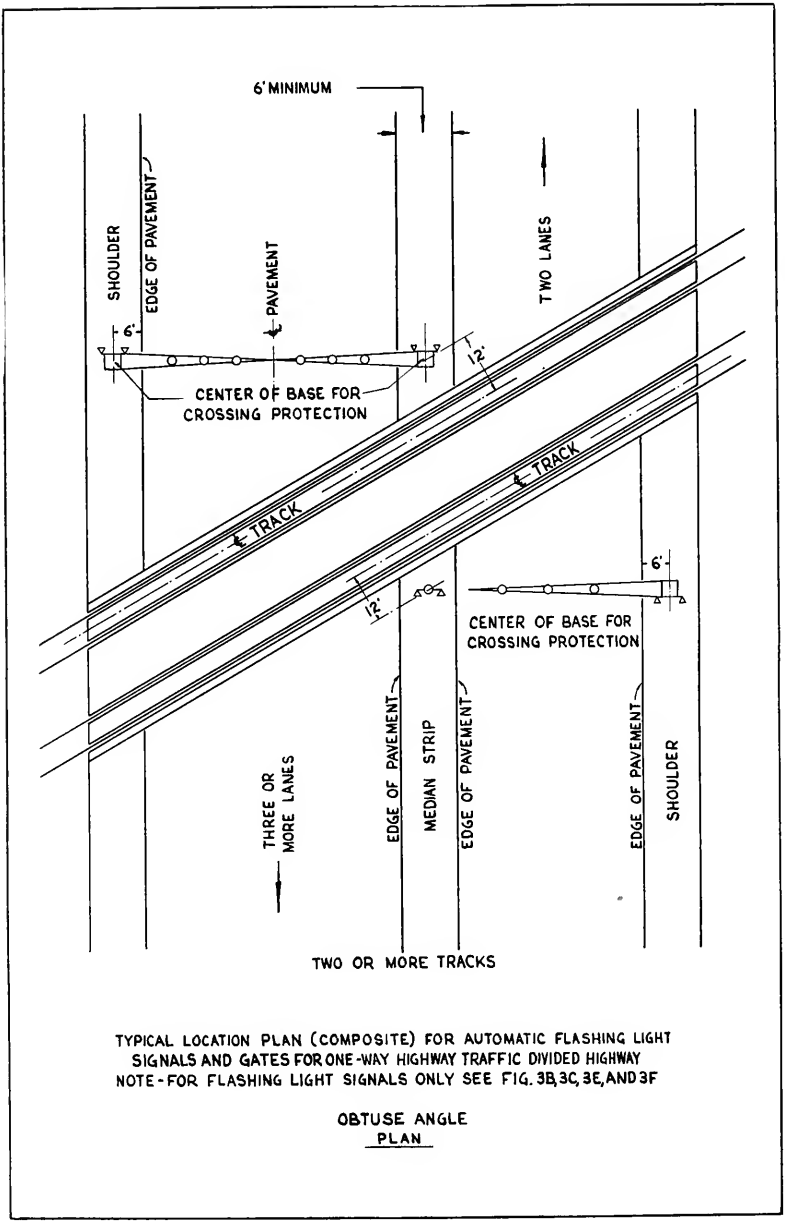
Fig. 3G.



TYPICAL LOCATION PLAN (COMPOSITE) FOR AUTOMATIC FLASHING LIGHT SIGNALS AND GATES FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY
NOTE - FOR FLASHING LIGHT SIGNALS ONLY SEE FIG. 3A, 3B, 3D, 3E, AND 3G

ACUTE ANGLE
PLAN

Fig. 3H.



TYPICAL LOCATION PLAN (COMPOSITE) FOR AUTOMATIC FLASHING LIGHT SIGNALS AND GATES FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY
NOTE - FOR FLASHING LIGHT SIGNALS ONLY SEE FIG. 3B, 3C, 3E, AND 3F

OBTUSE ANGLE
PLAN

Fig. 3J.

Report of Committee 13—Water, Oil and Sanitation Services

H. M. SCHUDLICH, *Chairman,*
D. C. TEAL, *Vice Chairman,,*
E. C. HARRIS, *Secretary,*

R. C. ARCHAMBEAULT
W. F. ARKSEY
R. A. BARDWELL
R. C. BARDWELL (E)
R. O. BARDWELL
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C. E. FISHER
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H. E. GRAHAM
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E. M. GRIME (E)
T. L. HENDRIX, JR.
T. W. HISLOP, JR.
H. M. HOFFMEISTER
A. W. JOHNSON
C. O. JOHNSON
J. J. LAUDIG
H. L. MCMULLIN
G. F. METZDORF
C. F. MUELDER
J. Y. NEAL
JOHN NORMAN
A. B. PIERCE (E)
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N. B. ROBERTS
J. P. RODGER
E. O. SALNERS
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C. B. VOITELLE
E. M. WALTERS
J. E. WIGGINS

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 260
2. Prevention of corrosion in steam and condensate lines.
   Final report, presented as information with the recommendation that the material be published in the Manual a year hence ..... page 263
3. Design, construction and operation of coach-servicing facilities to comply with regulations of U. S. Public Health Service, collaborating with Joint Committee on Railway Sanitation, AAR.
   Brief progress statement, presented as information ..... page 271
4. Cathodic protection of pipe lines and steel storage tanks, collaborating with the Electrical Section, AAR.
   Progress report, presented as information ..... page 271
5. Transportation of solids by pipelines, collaborating with the Pipeline Division, ASCE, and other interested organizations.
   Progress report, presented as information ..... page 274
6. Railway waste disposal, collaborating with Joint Committee on Railway Sanitation, AAR.
   Detailed progress report, presented as information ..... page 276
7. Inspection and maintenance of diesel fuel oil storage tanks.
   Brief progress report, presented as information ..... page 278

8. Methods of controlling spillage of fuel oil at diesel fueling and unloading stations.
Brief progress report, presented as information ..... page 279

9. Disinfectants, deodorants, fumigants and cleaning materials, collaborating with Joint Committee on Railway Sanitation, AAR.
Detailed progress report, presented as information ..... page 280

10. Railroad aspects of radioactive substances, collaborating with Joint Committee on Railway Sanitation, AAR.
Brief progress statement, presented as information ..... page 287

11. Methods of heating fuel oil to permit winter-time use of high-pour-point "economy" grade fuel oil.
Progress statement, presented as information ..... page 288

THE COMMITTEE ON WATER, OIL AND SANITATION SERVICES,
H. M. SCHUDLICH, *Chairman.*

AREA Bulletin 546, November 1958.

Report on Assignment 1

Revision of Manual

D. C. Teal (chairman, subcommittee), W. F. Arksey, R. A. Bardwell, M. R. Bost, T. W. Brown, R. E. Coughlan, J. J. Dwyer, H. E. Graham, T. W. Hislop, A. W. Johnson, C. F. Muelder, J. C. Roberts, E. R. Schlaf, C. B. Voitelle, E. M. Walters, J. E. Wiggins, R. C. Bardwell, A. B. Pierce.

Your committee feels that certain recommended practices now appearing in Chapter 13 of the Manual have been made out of date or completely obsolete by changing times and improved methods. In particular, some of the current Manual material on wood water tanks, track pans, pumps, etc., is no longer applicable.

This year we have reviewed Parts 1, 2 and 3 of Chapter 13 and offer the following recommended action with respect to the various specifications and recommended practices contained therein:

Pages 13–1–1 and 13–1–2

SUPPLY

Reapprove without change.

Page 13–1–3

USE OF TREATED WOOD FOR WATER TANKS

Delete.

Pages 13–2–1 to 13–2–16, incl.

PUMPING PLANTS

Reapprove with the following revisions:

Page 13–2–1—Change paragraph under Sec. B. Steam Equipment, to read: "At points where it is necessary to maintain a steam plant for other purposes, as at engine terminals, steam-operated equipment may prove economical."

Page 13–2–3—Under Sec. F. Deep Well Equipment, delete the first paragraph, which is ambiguous.

Substitute the following for the present second paragraph under Sec. F: "The most common types are the deep-well reciprocating pump, the deep-well centrifugal turbine pump, the submersible turbine pump, the air lift and the jet pump. When choosing a deep well pump, consideration should be given to the following features."

Page 13–2–4—Delete the third paragraph from top of page relative to the Moyno pump.

Add the following paragraph at middle of page, just above Sec. G: "Jet pumps have been found particularly adaptable for use in small drinking water wells because of their low initial cost, their simplicity and low maintenance requirements, and the ease with which they can be removed from a well for repairs."

Page 13–2–7—Under Art. 2. Suction Lines, change the fourth paragraph to read: "Genuine wrought iron pipe with welded or flanged joints is preferred for suction lines. Special care should be taken to make all joints absolutely tight, and the suction line should be laid with a slight grade toward the source of supply."

Page 13–2–8—Second paragraph from top of page, concerning discharge lines: Delete the last sentence, which reads "The use of lead for joints is usual, although under certain conditions other materials may be used to advantage."

Page 13–2–8—Under Art. 5. Service Lines, change paragraph (a) to read: "Service pipe materials may be divided into two general classes: the ferrous materials, of which genuine wrought iron, wrought steel and cast iron are examples, and the non-ferrous materials represented by lead, copper, brass, cement-asbestos and plastics. The ferrous materials are usually cheaper but the non-ferrous materials are more durable under certain conditions. Steel or cast iron pipe lined with cement or a bituminous material are also available."

Delete paragraph (f) concerning pre-caulked joints.

Change paragraphs (g) and (h) at bottom of page to (f) and (g).

Page 13–2–16—Delete entire Sec. N. Standardizing Valves and Packing for Water Service Pumps.

Page 13–3–1

SPECIFICATIONS FOR CAST IRON PIPE AND SPECIAL CASTINGS

Delete present specifications and substitute therefor the following: "Cast iron pipe and fittings shall conform to the latest American Standards Association (ASA) Specifications A–21 covering kind and class of material desired."

Page 13–3–1

SPECIFICATIONS FOR HYDRANTS AND VALVES

Delete present specifications and substitute therefor the following: "Hydrants and valves shall conform to the latest American Water Works Association (AWWA) Specifications C–500 covering kind and type of material desired."

Pages 13–3–2 to 13–3–5, incl.

SPECIFICATIONS FOR LAYING CAST IRON PIPE

Page 13–3–2—Under Art. 1. Material, delete the second and third paragraphs concerning specifications for cast iron pipe and fittings, etc. Change the fourth paragraph to read: "Lead for bell and spigot joints shall be first-class pig lead containing not less than 99.5 percent pure lead."

Page 13–3–3—Change the wording of Art. 7 from "Making Joints" to "Bell and Spigot Joints."

Page 13–3–4—Delete Art. 8. Prepared Joints, in its entirety and substitute therefor the following:

8. Mechanical Joints

The last 8 in outside of the spigot and inside the bell of mechanical joint pipe shall be thoroughly cleaned to remove oil, dirt and other foreign matter from the joint, and then painted with soapy water.

The cast iron gland is then slipped on the spigot end of the pipe with the lip extension toward the socket or bell end.

The rubber gasket shall be painted with soapy water and placed on the spigot end with the thick edge toward the gland.

The section of pipe shall be pushed forward to seat the spigot end in the bell and the gasket pressed into place within the bell, being careful to have it evenly located around the entire joint.

The cast iron gland shall be moved into position for bolting, all bolts inserted and nuts screwed up tightly with fingers.

All nuts shall be tightened with a suitable (preferably torque-limiting) wrench. The torque for various sizes of bolts shall be as follows:

Size (Inches)	*Range of Torque Foot–Pounds*
5/8	40–60
3/4	60–90
1	70–100
1 1/4	90–120

Nuts spaced 180 deg apart shall be tightened alternately in order to produce an equal pressure on all parts of the gland.

Page 13–3–4—Eliminate the parentheses in the paragraph under Art. 9.

Pages 13–3–6 and 13–3–7

SPECIFICATIONS FOR WOOD WATER TANK

Reapprove without change.

Pages 13–3–8 to 13–3–11, incl.

SPECIFICATIONS FOR TANK HOOPS

Reapprove without change.

Pages 13–3–11 to 13–3–13, incl.

SPECIFICATIONS FOR STEEL SUBSTRUCTURES FOR WOOD WATER TANK

Reapprove without change.

Pages 13–3–14 to 13–3–16, incl.

SPECIFICATIONS FOR TIMBER SUBSTRUCTURES FOR WATER TANKS

Reapprove without change.

Pages 13–3–17 to 13–3–27, incl.

SPECIFICATIONS FOR WELDED STEEL TANKS FOR WATER OR OIL STORAGE

Reapprove without change.

Report on Assignment 2

Prevention of Corrosion in Steam and Condensate Lines

J. J. Dwyer (chairman, subcommittee), R. A. Bardwell, I. C. Brown, T. W. Brown, P. J. Calza, B. W. DeGeer, D. E. Drake, E. C. Harris, A. W. Johnson, H. L. McMullin, C. F. Muelder, J. P. Rodger, E. O. Salners, R. M. Stimmel, D. C. Teal, A. G. Tompkins.

Corrosion in steam and condensate lines causes damage costing several million dollars each year. Your committee has studied ways and means of alleviating these losses, and presents its findings below. The subject is covered in three parts, viz., (1) discussion of the topic, with mechanical and design aspects, (2) use of volatile chemicals in the steam to neutralize acids—the neutralizing amines, and (3) use of chemicals to form a film barrier on metal surfaces—the filming amines. This is a final report, presented as information, with the recommendation that the material be submitted as Manual material next year.

1. Discussion

Steam condensate presents a very serious problem from the standpoint of piping maintenance, for it is generally of a corrosive nature and highly aggressive to piping materials. The greatest danger is due to deleterious gases which the pure condensate has absorbed. Of these, dissolved oxygen and carbon dioxide account for practically all of the corrosion found in condensate lines.

Carbon dioxide is generally the primary cause of return line corrosion. The major portion of this gas encountered in the steam cycle results from the decomposition of the bicarbonate or carbonate content of the boiler feedwater. Because of the carbonate and bicarbonate breakdown which takes place in the boiler, carbon dioxide is present in all types of steam regardless of the feedwater conditioning, except when feedwater is pure distilled water or equal. When the steam condenses, the carbon dioxide is absorbed by the condensate and forms a carbonic acid solution which is aggressive to both

the ferrous and nonferrous metals commonly found in return systems. Concentrations of 5 ppm or less are seldom troublesome, except where large amounts of steam are involved.

Dissolved oxygen present in an aqueous solution containing carbon dioxide has been found to produce a corrosive environment two to ten times more severe than would occur if only the carbon dioxide were present. The action of oxygen in accelerating a corrosive attack is briefly as follows: when water is in contact with a ferrous material, the initial corrosive action is the displacement by the iron of positively charged hydrogen ions from the water. The hydroxyl ions, with which the hydrogen ions were originally combined, unite with the soluble iron ions to form ferrous hydroxide. The liberated hydrogen ions migrate to the surface of the metal and form a protective film. If this film is left undisturbed, it tends to stifle further attack. However, when dissolved oxygen is present in the solution, it destroys the protective hydrogen film by uniting with the hydrogen to form water. The surface of the metal is thereby made available for further hydrogen liberation and the cycle repeats itself. A corrosive attack caused by dissolved oxygen can generally be identified by a pitting of the metallic surface, with the pits being wholly or partially filled with corrosion products. These nodules of corrosion products consist of a hard crust under which exists black magnetic ferrous oxide or red ferric oxide.

Steam condensate lines fail most often at threaded joints. Systems of pipes of dissimilar metals will greatly intensify rate of corrosion. Horizontal lines will usually be found more severely damaged than vertical lines, since the acid condensate will be concentrated over a small area along the bottom of the pipe and for much longer periods of time, due to the much slower flow rates in the horizontal sections. The corrosion damage will usually be found in the form of channeling or grooving of the bottom of the pipe due to carbonic acid, but pitting and oxide accumulations can be observed when oxygen is present. Sometimes fittings will be found to contain large accumulations of iron oxide deposits, which when removed will show little or no damage to the fittings themselves. This would indicate the corrosion taking place some place else in the system, probably with carbonic acid dissolving the iron, and then oxygen in the system converting the iron bicarbonate to ferrous hydroxide and on to ferric hydroxide, which will precipitate and settle at points of poor circulation or flow. Examples may be found which are primarily grooving, or primarily pitting, or combinations of both.

Good mechanical deaeration and chemical treatment of feedwater is the best insurance against oxygen leaving the boilers with the steam. Faulty traps, vents, valves, packing glands of vacuum pumps, etc., can permit oxygen to be drawn into the condensate system, especially with intermittent operation when vacuum is developed. Cold water injected to lower condensate temperatures may be saturated with oxygen.

Another type of failure, more mechanical than chemical, found in condensate lines is cavitation, resulting from steam collapse. This can occur when cold water, mentioned above, is injected into a condensate line to reduce temperature and to improve efficiency of condensate pumps. What happens is that the cold water causes instantaneous collapse of the steam in the line, creating tremendous shock forces sufficient to cause destruction of the pipe by cavitation effect. Steam collapse may be detected by hammering or banging sounds in the condensate line.

From the foregoing it will be apparent that good design is of the utmost importance in return line installations. Horizontal pipes should have not less than 4 in drop per 100 ft. If necessary to use dissimilar metals in the system, joints should be insulated.

The best quality of corrosion-resistant piping material, consistent with economic limitations involved, should be used. Double extra-strong wall pipe and fittings should be used for longest life. These mechanical and design recommendations can be summarized as follows:

a. Feedwater deaerators should be operated at or above 212 deg F and maintained in efficient condition.
b. All joints in return lines operating under sub-atmospheric pressures should be air tight.
c. All horizontal return lines should have sufficient slope to permit rapid and complete drainage.
d. All low points or pockets in lines where condensate could collect should be eliminated or properly trapped.
e. Condensate line pipe should be reamed to remove burrs.
f. Cold water injection into return lines ahead of vacuum pumps should be avoided.
g. Insulating unions should be used to connect dissimilar metals in the condensate system.
h. Double extra strong wall pipe and fittings should be used in condensate return lines.

Good design, construction, and operation of steam condensate return systems, as previously described, are quite important. By themselves, however, they are not sufficient to reduce maintenance costs to the minimum obtainable through the supplementary use of chemical treatment. These additional measures which may be utilized to extend maintenance savings already indicated are as follows:

1. Treatment of boiler feedwater to eliminate dissolved gasses.
2. Injection of chemicals into the steam that will carry along with the steam to neutralize any corrosive substances present.
3. Use of film-forming chemicals in the condensate system to prevent contact between the condensate and the metal surfaces.

Item 1 is a prerequisite of recommended boiler operating practice and is therefore outside the scope of this report. It is assumed that good boiler feedwater treatment must include the use of oxygen scavengers, such as sodium sulfite or hydrazine, to insure that steam leaving the boiler will be oxygen free. Items 2 and 3 are newer developments, which will be described in turn in the following pages of this report.

2. Neutralizing Amines

It has been noted that the primary causes of corrosion in condensate lines are carbon dioxide and oxygen; that these may be reduced or eliminated from feedwater by heating and deaerating; and that the carbon dioxide from the alkalinity of the boiler water may be reduced by suitable pretreatment methods. In spite of these measures, however, oxygen can re-enter the system, and carbon dioxide can be present also in the steam, and must be combatted with more drastic measures than heretofore described.

Attempts to neutralize condensate acidity with alkaline salts, such as caustic soda, soda ash, trisodium phosphate, or polyphosphate, have not been found practical or desirable; such chemicals return to the boiler, adding undesired alkalinity, it is difficult or impossible to disperse them uniformly through the steam system, and they act in

the same way as carryover from the boiler by leaving deposits in the steam piping, which is undesirable. A more satisfactory way to apply alkaline neutralizing chemicals would be in a volatile form which would disperse as a gas to all points reached by the steam and which would condense when the steam does. Certain inorganic and organic compounds of nitrogen have this ability, including ammonia and organic amines such as cyclohexylamine, morpholine, and benzylamine.

Ammonia was the first volatile nitrogen compound to be used for neutralization of carbonic acid and to increase pH, and can have a beneficial effect by reducing corrosion of ferrous metals; however, copper and zinc-bearing metals are rapidly corroded by ammonia, especially when oxygen is present. If feed is not completely deaerated, ammonia requirements may be high, creating an additional corrosion hazard to copper and zinc constituents.

The neutralizing amines—cyclohexylamine, morpholine and benzylamine—are much less aggressive on copper and zinc-bearing alloys, and have other protective characteristics superior to ammonia. They do not protect against oxygen; their primary function is to neutralize carbonic acid in the system. They must be applied in direct proportion to the concentration of carbonic acid present. Other disadvantages in addition to the lack of protection against oxygen are the large amounts required and high costs encountered. They find their best application, therefore, in systems with low makeup and low carbon dioxide content. They may have special advantages in high-pressure steam plants for turbine operation in combatting corrosive effects of carbon dioxide, hydrogen sulfide, and sulfur dioxide, which can cause accelerated attack on turbine blades. Morpholine, in particular, is very effective in this application. Treatment is usually based on amounts of these neutralizing amines needed to raise the condensate pH to 7.0 or slightly over.

An important consideration is the amines' distribution ratio, which is the ratio of amine in the steam to that dissolved in the condensate. For ammonia, this is rather poor, being 7 to 10 parts in steam for each part in water. For cyclohexylamine it is 2 to 4 parts in steam for one part in condensate; for benzylamine, 3 to 4 in steam to one in condensate; for morpholine it is 1 in steam to 2 in condensate, which gives it the most favorable distribution ratio of the three amines. This is quite an advantage for morpholine, since the treatment objective is to get the amine out of the steam and dissolved in the condensate, where it must be before it can neutralize any acid.

Analytical methods of dosage control may be by means of standard pH meter, modified colorimetric pH methods, actual titration of dissolved carbon dioxide, and/or colorimetric determination of neutralizing amine content, using a copper salt which forms a characteristic blue color from the presence of a copper-amine complex, the strength of the blue color being proportional to the amount of amine in solution. In addition to analytical methods, field test corrosion devices inserted in condensate lines are used to measure the extent of corrosion actually taking place.

In feeding neutralizing amines, slug feed methods are most common, but least desirable, for the reason that these chemicals are expensive, and the most efficient and economical dosages are obtained by proportioning–continuous feed methods. They can be added to the chemical vat with phosphate and/or alkaline salts and fed to the boiler in proportion to the makeup required.

All three of the amines considered are skin irritants and should be handled as such; however, at the dosages used in the steam and condensate they are not toxic and will not cause intestinal disturbances. Nevertheless, if they are to be used in steam which

SUMMARY OF CHARACTERISTICS

Ammonia	Cyclohexylamine	Benzylamine	Morpholine
(a) Distribution Ratios (parts in steam per part in condensate):			
7-10	2-4	3-4	0.4
(b) Dosages to adjust pure water to pH 9.0:			
0.2-0.5 ppm in water 1.4-2.0 ppm in steam	2.0 ppm in water 4-8 ppm in steam	2.2 ppm in water 6-8 ppm in steam	4.0 ppm in water 1.6 ppm in steam
(c) Dosages to neutralize condensate to pH 7.0:			
	3.0 ppm(60%) /ppm CO_2	2.2 ppm/ppm CO_2	1.6 ppm/ppm CO_2
(d) Neutralizing value (dosage to bring water containing 10 ppm CO_2 to pH 7.4):			
	20 ppm	22.05 ppm	19.8 ppm
(e) pH of dilute solution of amine bicarbonate:			
	8.1	7.8	7.4
Concentrates excessively. May attack copper, brass. Has high alkalinity suitable for all-iron system. Requires excessive amounts in steam to get adequate pH of condensate.	Compounds with CO_2 do not hydrolyze freely. High alkalinity tends to prevent CO_2 removal, increases percent recirculation and CO_2 concentration. Readily lost during deaeration and at vent. Low losses in blowdown. Minimum attack on copper and brass. Small loss of CO_2 from compounds causes large pH increase. Amine bicarbonates can cause plugging.	Intermediate in alkalinity between cyclohexylamine and morpholine. Causes some recirculation of CO_2. Moderate losses, blowdown and deaeration. Intermediate CO_2 removal from system. Has pungent odor.	Lower alkalinity allows CO_2 removal in feedwater heater. Lower volatility, so greater blowdown losses. Concentration decreases during distribution of steam at low pressure (5 psig and less). No attack on copper or brass. Large CO_2 release has minimum effect on pH. No plugging (morpholine bicarbonate very soluble)

is used for direct cooking or processing of food, it would be wise to make a study of the medical aspects, and Food and Drug Administration views on the particular application involved.

3. Filming Amines

These inhibitors function by establishing a non-wettable film on metal surfaces in contact with condensate. This film is mostly one molecule thick and does not tend to increase with continued treatment. These filming agents are required in low dosages of only 1 to 3 ppm and are independent of the concentrations of carbon dioxide and oxygen, since they do not combine chemically with these corrodents.

The most effective filming inhibitors are saturated, straight-chain primary aliphatic amines and their salts, with chains of 10 to 18 carbon atoms. Octadecylamine and octadecylamine acetate are typical examples. Branched-chain and unsaturated-chain amines, as well as tertiary amines, are less effective. These inhibitor molecules have a polar end, which adsorbs to a metal surface, and a long water-insoluble carbon chain. They function by forming an adsorption layer over the metal surface, but their efficiency may be low until the inhibitor molecules are perpendicular to the metal surface, which generally occurs at the critical concentration, above which packing can begin. These molecules then will be all standing on end with their polar extremities being packed so closely together that no metal surface will be left exposed to the condensate. The more tightly packed they are, the more complete the protection will be. When an effective film has been formed, the free space left between the adsorbed polar ends of the inhibitor will be smaller than the molecules of water, oxygen, or carbon dioxide, thus preventing contact of these with the metal. It is thus theoretically possible to obtain 95 percent or better protection.

Another ability of the filming amines is to displace and remove corrosion products. By this cleaning action on the metal surfaces, heat transfer rates in heat exchangers and condensing equipment are improved. Since the film formed is non-wettable, dropwise condensation of the steam is promoted, thus further improving heat transfer.

Some of the inhibitor may be expected to combine with old fouling deposits, rust, sludge, carry-over, etc., and would not then be available for formation of the isolating film desired, and would constitute a loss. But since the deposits, if removed too rapidly, might clog traps and strainers, initial dosages of treatment should be kept low, with gradual increases as the system is cleaned up. Some additional losses will occur at condensate drips, by blowdown, and in condensate returning to the boiler.

Octadecylamine is the most commonly used filming amine, but since it is insoluble in water, its water-dispersible salt, octadecylamine acetate, is normally used. This dry flake acetate form is readily dispersed in hot condensate to make 1 percent solutions which produce a pH of approximately 5.5. These solutions will hydrolyze to form traces of acetic acid, for which reason chemical vats should be rubber or plastic lined, or of aluminum. If the acetate solution is injected into steam lines, flashing may occur, with similar hydrolysis and acid formation, resulting in minor corrosion of the chemical line and steam line near point of entry. This corrosion can be eliminated by injection direct to the boiler, since free octadecylamine is liberated in the boiler water and volatilizes with the steam. Octadecylamine acetate solutions should not be fed direct to superheated steam systems due to the formation of amine-acetamides, which cause deposits in the boiler and feed systems, and are less effective inhibitors. For the same reason neither should they be fed to saturated steam systems ahead of pressure-reducing valves, etc., which could cause localized superheat conditions.

A further improvement over octadecylamine and octadecylamine acetate has been the development of a high-strength filming amine inhibitor which is 100 percent self dispersing and is available both is a dry flake and as a 20 percent emulsion resembling cold cream. Since the flake material melts at 115 deg F and might, therefore, melt and cake in containers, the 20 percent emulsion is the more desirable form. A 1-percent solution of these high-strength filming inhibitors contains no acetate or acetic acid and has a pH of 8.5 to 9.5, eliminating the corrosion hazards to vats and piping which might occur with octadecylamine and its salt. These high-strength amines may be fed, therefore, either to boilers or steam headers. Procurement specifications for filming

amines should require a minimum active inhibitor content in order to obtain an equivalent basis for cost comparisons and dosage calculations.

Octadecylamine acetate is not compatible with hardness in water or with alkaline or neutral salts, for which reason it cannot be fed with other water treating chemicals, and which requires also that condensate or equivalent be used for dilution in the separate chemical vat required. The high-strength filming amines, on the other hand, are compatible with moderate amounts of hardness and other water treating chemicals, but where injecting into steam headers, condensate is recommended to avoid deposits in the steam lines.

Proportioning chemical pumps are recommended for applying filming amines to boilers or steam lines. Slug feeders and by-pass type feeders are not recommended because of non-uniform feed rates. Neither should these amines be fed into the boiler feed lines. Filming amines displace oxides and other fouling deposits to clean the metal pipe surfaces, which will then be more subject to corrosion than when protected by the oxide or other metal coatings. This is the reason for continuous feeding being required, rather than slug or intermittent types.

Potential skin irritating characteristics of amine inhibitors in concentrated forms should be recognized, and continuous skin contact should be avoided. These materials should be removed from the skin by thorough washing with soap and water. Handling precautions specified by the manufacturer should be observed. Possible toxicity considerations should not be overlooked. While concentrations used in steam for condensate line protection are not considered harmful, government agencies prohibit their use in live steam used to process milk and foods. These objectives have been overcome by the use of heat exchangers to produce steam from uncontaminated feedwater for such special purposes. Significant reduction of corrosion should be evident after one month of continuous application of a filming amine, but up to 6 months or longer may be required to obtain the desired protection of 95 percent or better. Efficiency of the amine treatment may be checked by various types of testers available for insertion into the condensate system. It may be checked also by analytical determinations of dissolved iron in the condensate. Severe corrosive conditions might produce 50 to 100 ppm iron in the condensate, but effective control by filming inhibitors should limit the iron to less than 1 ppm.

In summary it may be said of the filming amines that:

a. They may be applied in low, economical dosages to effectively control corrosion in condensate systems and on condensing surfaces with considerable savings in maintenance.
b. Dosages required are independent of concentrations of the dissolved gases.
c. Both oxygen and carbonic acid are controlled.
d. They increase heat transfer rates by removing deposits and promoting dropwise condensation.
e. Optimum results are obtained by continuous application in the range of one to three ppm.
f. Corrosion control progress may be evaluated by various types of testers and by chemical test methods for iron in the condensate.
g. Field test methods are available for determination of residual amine.

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5. Acknowledgement

The committee wishes to thank L. S. Heasom, R. G. Angell, and J. F. Wilkes for contributing information which has been helpful in the preparation of this report.

Report on Assignment 3

Design, Construction and Operation of Coach-Servicing Facilities to Comply with Regulations of U. S. Public Health Service

Collaborating with Joint Committee on Railway Sanitation, AAR

J. M. Bates (chairman, subcommittee), R. C. Archambeault, V. C. Barth, M. R. Bost, I. C. Brown, V. R. Copp, D. E. Drake, H. E. Graham, T. L. Hendrix, Jr., H. L. McMullin, C. F. Muelder, A. B. Pierce, J. C. Roberts, E. R. Schlaf, J. E. Wiggins, Jr.

Your committee is initiating a study of hydrant types currently in use on the railroads to establish the scope of the problem.

Cursory inquiry indicates the problem to be of sufficient magnitude probably to warrant investigation and design by the AAR Research Center of an acceptable hydrant which will satisfy the following objectives established for this assignment, namely, that it will

a. be acceptable to the U.S.P.H.S.,
b. be economical to manufacture,
c. be simple in construction,
d. require little or no maintenance,
e. be practical in cold climates.

It is expected that the committee's study will be sufficiently advanced before the 1959 deadline for submissions of requests for research that it will be possible to justify the need and satisfy other basic requirements for an appropriation and research project in 1960.

Report on Assignment 4

Cathodic Protection of Pipelines and Steel Storage Tanks

Collaborating with Electrical Section, AAR

W. F. Arksey (chairman, subcommittee), R. E. Coughlan, B. W. DeGeer, J. J. Dwyer, H. E. Graham, T. I. Gray, T. L. Hnedrix, Jr., A. W. Johnson, C. O. Johnson, J. Y. Neal, J. P. Rodger, H. E. Silcox, H. W. Van Hovenberg.

In its report published in the 1957 Proceedings your committee outlined the mechanism and possibilities of cathodic protection, the theory of corrosion and of cathodic protection, and the economies to be realized by application of cathodic protection to railroad facilities under the headings: A. Introduction to Cathodic Protection, and B. Cathodic Protection Technical Practices. The following report is a continuation of the previous report and is offered as information.

C. INSTRUMENTATION

This report covers instrumentation insofar as it relates to choice of instruments and their application to field surveys preliminary to the installation of cathodic protection systems.

In making a field survey it is necessary to measure electrical potentials and currents associated with corrosion of the facilities in question. When cathodic protection has been applied to an installation, electrical measurements are made to determine when corrosion is halted. The corrosion potentials and current normally measured are small,

extending down to millivolts and microamperes. However, cathodic protection and electrolysis currents range from milliamperes to hundreds of amperes. Therefore instruments must cover a wide range of current and potential measurements. Improperly taken measurements in the field may result in data calling for a cathodic protection system which may only partially protect or considerably over-protect the system.

Practically all direct-current instruments used in the field for measuring current and potentials are of the moving-coil type. Deflection of the needle depends upon the amount of current flowing in the moving coil; hence, most millivolt voltmeters and milliamp ammeters are essentially microammeters. M.C. Miller's paper listed with others at the end of this report goes into detail on instruments. He is an authority in the field, and it is recommended that those interested obtain a copy of this paper for their use.

Highly sensitive instruments have moving coils and pointers that are delicately supported and perfectly balanced. Therefore, unless the coil is properly damped, the pointer will over-travel the reading and oscillate back and forth until it gradually comes to a stop. Field instruments with suitable period and damping and which do not require accurate leveling are obtainable for ranges of readings used.

Potential Measuring Instruments

Four types of millivolt voltmeters are used.

1. Low-resistance instruments
2. High-resistance instruments
3. Potentiometer voltmeters
4. Vacuum-tube voltmeters

A study of the characteristics of the various instruments offered in this field should be made before choosing a particular instrument. There are two general rules which should be followed:

*1. "The instrument sensitivity should be of such order as not to pass sufficient current to change the potential being measured nor polarize the reference electrode being used, thereby changing its half-cell potential."

*2. "The internal resistance (if moving coil and series resistors) should be very high compared to the external resistance of leads and resistance to earth of reference electrodes. If readings with 1 percent accuracy are required, the instrument resistance must be 99 times as high as the resistance of leads, contacts and electrodes (unless corrections are made for external resistances)."

To illustrate the application of various instruments named to typical measurement problems, a few examples are cited: Any suitable *voltmeter* having the required range may be used to measure battery and rectified potentials. A *potentiometer* would be desirable for measuring structure-to-structure potentials, provided that necessary precautions are taken in its operation. A *high-resistance voltmeter* (50,000 to 500,000 ohms-per-volt sensitivity) may be used to measure structure-to-earth potentials, using a reference electrode. In using a high-resistance voltmeter the precautions set forth in the preceding paragraph should be taken very carefully. The potential could also be measured correctly by using a *potentiometer* properly adjusted. Either a *low-resistance* or a *high-resistance voltmeter* could be used for measuring potential between a structure and

* M. C. Miller, electrical engineer, "Characteristics and Field Use of Electrical Instruments for Corrosion Investigation and Cathodic Protection."

an anode. A *very high-resistance millivoltmeter* is desirable for measuring earth potentials where it is desired to determine the direction of flow of stray currents and galvanic currents through the earth. A *potentiometer* may also be used if care is taken in adjusting it. Measurement of currents involved in cathodic protection require a variety of instrument characteristics similar to those required in potential measurement. Currents measured vary from hundreds of amperes to a few microamperes, requiring a number of instruments.

A multi-combination meter has been developed specifically for field and laboratory testing. All the instruments required for electrolysis and corrosion investigations and cathodic protection testing have been combined into one compact instrument. It has two highly sensitive micro-ammeters assembled in one case, with various switches to cover a complete range of potential from 2 mv to 100 v, and current ranges from 1 milliamp to 20 amp. It provides a low-resistance millivoltmeter, a high-resistance millivoltmeter and a potentiometer using a calibrated galvanometer with seven calibrated ranges. These meters are furnished with complete wiring diagrams and instructions for their operation.

It is suggested that anyone buying equipment for making cathodic protection tests should experiment in an earth-filled box moistened slightly with water to increase its conductivity. By use of such a box proficiency in the operation of the meter can be developed, and first-hand knowledge of galvanic currents between various metals can be obtained.

Another ground-resistance measuring instrument contains a balancing galvanometer and potentiometer which gives true ground-resistance readings to 1/10 ohm times the range multiplier. The range selector switch allows multipliers of 1, 10, 100 and 1000 to be used in measuring resistances. When taking resistance measurements, neither the length of leads nor stray a–c or d–c currents from outside sources affect the accuracy of the readings. Such an instrument is used for making soil resistivity tests, anode resistance tests, circuit resistance tests, polarization effect, and current density. It is also necessary to have a suitable voltmeter for measuring potentials in connection with the instrument just described.

In addition to the instruments for measuring potential current and resistance it is necessary to have a copper sulfate or other type electrode as a reference electrode, and for making resistance tests of soils in the laboratory it is necessary to have a standard soil box. The copper sulfate electrode is a plastic tube in which a copper rod is immersed in copper sulfate solution. The bottom of the tube is closed by a porous plug through which contact is made with the ground. The soil box is approximately 1½ by 2 by 9 in, made of plastic or other suitable material. The dimensions are such that when the soil box is filled level full with electrolyte, such as soil, water or other liquid, the resistivity in ohm centimeters of the contents is equal to the *change-in-potential* between the center or potential pins divided by the *change-in-current*. If the current is in milliamperes, then

$$\frac{\text{Delta mv}}{\text{Delta}} = \text{ohms centimeter}$$

A high-resistance voltmeter or millivoltmeter should be used for obtaining the potential differences. The ground resistance meter or a milliammeter and suitable millivoltmeter, electronic voltmeter or potentiometer may also be used.

In addition to the foregoing information, the following bibliography is submitted containing a number of papers which may be obtained for more detailed study:

A

Corrosion and Its Control—Marshall E. Parker, Published by The Oil and Gas Journal

Galvanic Couples and Cathodic Protection—M. C. Miller

Corrosion of Buried Metals and Cathodic Protection—M. C. Miller

Characteristics and Field Use of Electrical Instruments for Corrosion Investigations and Cathodic Protection—M. C. Miller

Cathodic Protection for Earth-Buried Pipelines and Other Metal Structures—Bureau of Mines Cir. 7827—April 1958.

Zinc as a Galvanic Anode Underground—American Zinc Institute, 60 E. 42nd St., New York, N. Y.

Zinc as a Galvanic Anode Underwater—Ditto

How Zinc Controls Corrosion—Ditto

Proceedings of 2nd Annual Appalachian Underground Corrosion Short Course 1957—Technical Bulletin No. 48, Engineering Experiment Station, West Virginia University, Morgantown, W. Va.

This report is submitted as information with plans at present to complete the report next year.

Report on Assignment 5

Transportation of Solids by Pipeline

Collaborating with the Pipeline Division, ASCE, and Other Interested Organizations

E. M. Walters (chairman, subcommittee), R. C. Archambeault, R. O. Bardwell, I. C. Brown, T. W. Brown, C. E. DeGeer, T. I. Gray, E. M. Grime, T. W. Hislop, J. J. Laudig, J. Y. Neal, John Norman, N. B. Roberts, A. G. Tompkins.

Your committee submits the following report of progress as the first of a series of reports in the gathering of information on the transportation of solids by pipeline.

The use of pipelines for short distance transportation of solids as such, and as slurries, has been in use by many industries for some time and the principles have been worked out in some detail.

Interest in long-distant transportation has developed in the past few years, and at the present time there are several installations ranging from a few miles to over a hundred miles long in operation or in planning stages.

In the past two years, two solids-carrying pipelines have been put into commercial operation in the United States. One is a 72-mile pipeline used by the American Gilsonite Company at Grand Junction, Colo., the other a 108-mile pipeline in Ohio.

The American Gilsonite Company's pipeline is 6 in. in diameter and delivers 700 tons per day of Gilsonite from the mine head to the refinery. This line was installed at a cost of $2,000,000 and eliminated truck transportation of ore over a 180-mile route. Operating costs are $1.00 per ton, which makes this method of transportation feasible.

Ore is crushed to 8-mesh size, de-sanded, and mixed with water to form a 35 percent solids—65 percent water slurry which is kept continuously agitated until delivered to the pipeline.

The pump station consists of three 300-hp reciprocating pumps (two operating and one standby) which supply the pipeline at the rate of 350 gal of slurry per minute at a pressure of 2100 psi. Line velocity is 4 ft per sec. and minimum pressure is 200 psi.

The particles tend to settle if the line is not kept under pressure, so a back pressure of 1150 psi is maintained at the discharge, controlled by cutting in and out a series of small diameter pipes.

The experimental work to develop the mechanics of operation was performed at the Colorado School of Mines. Erosion of the pipeline was tested by radioactive methods and found to be negligible. Corrosion is controlled by means of sodium sulfite. A chemical dispersing agent was tested to prevent solids separation but test results were not of too much direct value in commercial installation. Slurries up to 41 percent solids were found feasible by test, but 38 percent is the highest used in practice to date.

The pipeline goes over a 2000-ft mountain range, and a reservoir is maintained at the highest point for back flushing the line in case of plugging or pump failure.

The Pittsburgh Consolidated Coal Company is now delivering 3600 tons of coal per day to the Cleveland Electric Illuminating Company through a 10-in pipeline 108 miles long, which replaces an equivalent haul by rail at a cost of 40 percent of rail charges.

The preparation plant crushes, de-sands, and grades the coal to 14-mesh size and delivers a 50 percent solids—50 percent water slurry to storage lagoons at the rate of 300 tons per hr. It operates 5 days per week and keeps the pipeline operating 24 hr per day 7 days per week.

Three 450-hp reciprocating pumps at three stations 30 miles apart maintain a pipeline flow of 530 gpm at a velocity of 4.5 ft per sec and a pressure of 1000 psi. The coal will not pack at zero velocity, and will reform a slurry as the velocity increases.

Erosion is not much of a problem as the coal is clean, soft, and sightly greasy, and sharp edges are soon rounded off.

Outside corrosion is combatted by an enameled glass cloth covering and cathodic protection. Interior corrosion is controlled by adjusting the pH to 6.5 with caustic, using an inhibitor, and using a nitrogen atmosphere in the surge tanks.

On delivery, the slurry is dewatered in thickeners, vacuum filter, flash dryers, and a cyclone collector.

To be economical, large volumes of coal must be handled, and the form must be that used in the final process.

A projected Russian pipeline 6 in. in diameter is to deliver 200 tons per hr of minus ¼-in coal a distance of 41 miles between a mine at Novovolynsk and the Dobrotvorsk power station. This line will operate at 1000 psi and will handle a 39 percent solids—61 percent water slurry at a velocity of 4.8 ft per sec. It is expected to show a savings of 60 percent over present rail transportation.

A 500-mile pipeline for delivering sulfur is mentioned as being planned in Canada.

The International Nickel of Canada has been using a 7½-mile pipeline for delivering ore to the refinery and to dispose of tailings.

Conclusion

Long-distance transportation of solids by pipeline is attracting more and more attention and extensive research is underway on this problem. The railroads should maintain an interest in the development of these pipelines so as to take advantage of their economic aspects.

An outline of the items to be investigated in the future is as follows:

A. PUMPS AND PIPELINES

1. Types and Operating Pressures
2. Materials of Construction

3. Corrosion and Erosion Problems
4. Life and Replacement
5. Power Requirements

B. SLURRIES

1. Density
2. Velocity
3. Particle Size, (a) Methods of Forming, (b) Size Control
4. Methods of Forming and Maintaining Slurries
5. Methods of Dewatering Slurries

C. ECONOMICS

AREA Committee 16's current report on Assignment 11 gives a comprehensive review of the advantages and disadvantages of long-distance pipeline transportation of solids.

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Report on Assignment 6

Railway Waste Disposal

Collaborating with Joint Committee on Railway Sanitation, AAR

T. A. Tennyson (chairman, subcommittee), R. C. Archambeault, R. C. Bardwell, J. M. Bates, I. C. Brown, V. R. Copp, R. S. Glynn, T. I. Gray, E. C. Harris, C. O. Johnson, H. L. McMullin, G. F. Metzdorf, J. Y. Neal, J. C. Roberts, E. O. Salners, E. R. Schlaf, R. M. Stimmel, A. G. Tompkins, E. M. Walters, J. E. Wiggins, Jr.

Your committee submits the following report of progress in gathering data on railway waste-disposal practices, which has been carried out in addition to its regular perusal of the literature available on this subject. This current report shows how progress has been carried out on this assignment by dividing the subcommittee into task groups, each with its own phase of the over-all project. Response to this approach has been good, and the status of our work is summarized in the following paragraphs.

Regulation of waste disposal by state and federal groups, as well as by interstate agencies, is tending toward uniformity as the result of the 1956 Water Pollution Control Act, which encourages interstate compacts, uniform state laws, and provides for money to carry on such activity for a five-year period. Most states now have water pollution control boards which administer laws requiring permits to discharge wastes from new sources, and the trend appears to be toward requiring approval of plans prior to new construction. It would appear that more effort may be directed toward establishing

waste levels for given streams and localities rather than to set up fixed limits to cover an entire state.

Since the major problem in disposal of liquid wastes from railway property is concerned with oil, one of our groups is making a study of ways and means of controlling the amount of oil wasted. They will investigate and approximate the relative responsibilities for losses and wastage of railway fuel oil, lubricating oil and cleaning material between (1) employee handling practices and techniques, and (2) equipment design, construction and its automatic operation. A reduction of the amount of oil placed in the liquid wastes will not only reduce the nuisance of its disposal but can well result in dollar savings to the railroads by stopping leaks, spilling and other wasting of oil.

Cleaning-vat wastes, due to their high content of emulsified oil and chemicals, should be handled separately from general shop storm water where possible. Such wastes should be neutralized, followed by settling of sludge and removal of floating oil, and preferably further dilution, before disposal into the waste water system. If emulsions become a problem, it can often be solved by retention in a large lagoon from which water can be drawn from below the surface by means of a down-turned outflow pipe. Chemical treating methods can also be used to facilitate separation of the phases prior to primary separation in conventional oil traps or sedimentation in lagoons, tanks, basins, etc.

The recommended primary separation method for oil and solid wastes from water is the gravity-type oil trap, which can be either shop constructed or purchased from a number of suppliers. The design and operation of such traps have been completely discussed in previous reports of your committee, as well as in publications of the American Petroleum Institute, such as its Manual on Disposal of Refinery Wastes. Other methods which could be considered primary under certain conditions are filtration through various media and absorption by hay, coke, etc.

In the treatment of certain industrial wastes, particularly those containing oil, of the water-borne type, chemical flocculation and precipitation can be quite useful. The processes involved are very similar to those utilized in the treatment of water for steam generation, which are well known, as are also the reagents used to carry out these operations. Frequently, flocculating agents require aids for best results. In this connection, acids and alkalis are used to bring the pH value of the fluid being treated to the optimum level for the flocculent being used. Absorptive clays, such as bentonite and Fuller's earth, may be used as nuclei for floc formation. Activated or collodial silica can also be used for this purpose. Because of the multiplicity of water characteristics and end uses of effluent, no single rule can be formulated regarding the use of flocculating agents. Each problem must be studied carefully to determine the most effective and economical material for the job at hand. On many railroads, particularly those still operating some coal-burning power, provisions should be made for settling out grit and other solids ahead of the flocculation process, and considerable effort might well be expended toward designing as nearly automatic operation as possible.

While experience has shown that gravity oil separators are producing satisfactory effluents in most cases, without chemical methods or any final clean up, there are situations in which persistent oil emulsions can bring on complaints, and in these cases something more must be done. If the primary separation has been good, or flocculation has further reduced the oil load, then some method such as filtration, absorption, etc., as described above, can be used. Under certain conditions it has been found feasible

to remove the last traces of oil and other organic compositions, including phenols, by biochemical action in such a device as a trickling filter.

Disposal of waste materials recovered from oil separators can become, of itself, a major problem. The waste oil must be removed from the immediate area of the disposal plant and kept from re-entering the sewer system by seepage or by being carried in by storm water. If the quantity of floating oil collected from the oil skimmer is large, several storage lagoons may have to be built, and these should be placed on high terrain and walled with relatively impervious dikes.

Final disposition of waste oil depends on several factors characterized by local conditions, physical properties and quantity of the oil involved. It is considered good policy to obtain a laboratory analysis of the oil in question. This would include determination of API gravity, water and sludge content plus any other test which might help reveal the general characteristics of the oil and help to determine its possible use. Oils which are reasonably free of water, sludge and other impurities, and have gravity between 10 and 30 deg API, may be used for power plant boiler fuel. Some railroads find it advantageous to sell or give their waste oil to highway departments for use on rural roads. Termite exterminators may often prove to be a ready market for such oil, and it may also be possible to use some of it for weed control. If the oil is unsuitable for fuel, and cannot be sold or given away, it may be disposed of by burning in open-air pits, provided smoke laws do not prohibit this.

The disposal of solids removed from liquid waste treatment plants and the general trash and rubbish—such as cartons, paper, wrappings and sweepings—which comprise the bulk of waste material generated around railway property, can introduce troublesome and often costly handling. In order to reduce waste-disposal costs, the man-hours devoted to the flow of this material must be lowered to a bare minimum, which calls for mechanization wherever possible. In planning the disposal of these materials three points must be considered: (1) waste generation, (2) temporary storage facilities and (3) movement of waste into the final disposal area. The use of enclosed containers which can be easily handled by trailers, fork lift trucks, etc., as temporary storage facilities has been worked out quite thoroughly by a number of firms which are in this particular business, and use of these systems can often save considerable sums in labor costs. The final disposal area must be carefully selected if the railroad does not have the use of the municipal sewerage system, incinerator, dump or land fill area for waste disposal.

This report is presented as information.

Report on Assignment 7

Inspection and Maintenance of Diesel Fuel Oil Storage Tanks

A. W. Johnson (chairman, subcommittee), V. C. Barth, M. R. Bost, P. J. Calza, V. R. Copp, B. W. DeGeer, C. E. DeGeer, H. M. Hoffmeister, C. O. Johnson, J. J. Laudig, John Norman, J. C. Roberts, N. B. Roberts, H. E. Silcox, H. W. Van Hovenberg, C. B. Voitelle, J. E. Wiggins, Jr.

Your committee recommends the following procedure for maintaining diesel fuel oil storage tanks and insuring good-quality fuel oil:

These tanks are either a combination of a storage and service tank or a large storage tank above ground with a smaller underground service tank. They should be inspected at six-month intervals, spring and fall, primarily to determine the amount of

sediment or water accumulation in the bottom. This can be removed from above-ground tanks through a valved bottom drain and from buried tanks by either a portable or stationary pump, power or hand-driven, depending on size of tank.

Fuel samples are taken by a qualified inspector using a "tank thief", a sampling device having a cast aluminum case 4 in. in diameter by 12 in long with a spring-actuated butterfly valve at the bottom. A chain is used to lower and raise the "thief." It is open at both ends when lowering, and the bottom valve can be closed at any level to take a sample. If lowered to the tank bottom, the valve closes automatically ⅛ in above the bottom. Usually, samples are taken at the half-full level and at the bottom and sent to the test department for analysis and report. Accumulation of water and sediment over a 6-months period usually is negligible, but measurements 2 in deep or more in buried tanks may indicate surface leakage either through the tank roof or shell. Underground tanks are more subject to such leakage, and leaks are more difficult to locate and repair.

Inspection of tanks to determine their general condition and the extent of repairs needed should be made annually.

Service piping from tanks should be arranged so that the entire depth of fuel can be used or circulated if necessary.

Report on Assignment 8

Methods of Controlling Spillage of Fuel Oil at Diesel Fueling and Unloading Stations

V. C. Barth (chairman, subcommittee), R. C. Archambeault, W. F. Arksey, M. R. Bost, T. W. Brown, P. J. Calza, V. R. Copp, D. E. Drake, C. E. Fisher, H. E. Graham, H. M. Hoffmeister, G. F. Metzdorf, C. F. Muelder, John Norman, N. B. Roberts, J. P. Rodger, E. O. Salners, E. R. Schlaf, R. E. Silcox, T. A. Tennyson, Jr., C. B. Voitelle.

A survey made on several railroads revealed that it is generally the practice to unload fuel oil from tank cars by overhead unloading facilities with drop hose counter-balanced and with or without a swivel joint. Filters are generally employed somewhere in the system to insure clean fuel oil. A limited number of railroads employ bottom unloading. Fuel spillage loss by bottom unloading appears to be low. In several cases, the pumps used to unload tank cars are also used to fuel diesel engines.

The estimates of individual railroads vary considerably as to the amount of fuel oil loss resulting from overhead unloading. Almost the entire loss is represented by the amount of fuel oil remaining in the bottom of the tank car after the unloading operation is completed. This includes fuel spilled back into the tank car as suction is lost by the drop hose. The estimated loss varies from a few gallons to as high as 50 gal per car. The average loss is approximately 25 gal. Several railroads consider the fuel left in the tank car not a true loss, because it is usually contaminated with both sediment and sludge.

With respect to automatic shut-off fueling facilities for diesel locomotives, it is generally estimated that they save 2 gal of fuel oil for each locomotive refueled. Such devices automatically shut off the fuel when the tank becomes full, thus eliminating spillage out of the overflow pipe.

It is generally agreed that with proper handling, the amount of fuel loss from the fuel pipe with conventional equipment when uncoupling is relatively small, except

in instances where the delivery pipe is long and the track is not level. In these cases a system which prevents spillage from the fuel line when uncoupling could result in substantial savings of fuel.

In a few instances, automatic fueling devices have been in operation for as long as 5 years with a delivery rate of 300 gpm, and reports indicate the equipment is satisfactory for service requirements. Many railroads are now in the process of testing special automatic devices, from which definite results and conclusions are not as yet available.

Several railroads feel that automatic shut-off devices are not necessary if the fueling is carefully supervised and speed is not a major factor. However, most railroads believe that the fuel waste encountered in fueling operations is considerable and creates a fire hazard.

Since there are several automatic shut-off type fueling devices now available, or in the experimental stage of development, the evaluation and adoption of such equipment are largely dependent upon standardization and interchangeability of such equipment; for example, efficient use of such equipment must permit fueling of diesel locomotives with any one of the various types now under consideration, including present conventional devices.

It is impossible for the committee to establish the economics of these unloading and fueling devices until the various types are fully evaluated. The committee is now undertaking this phase of its work, and expects to complete its investigation within the next year.

This progress report is presented as information.

Report on Assignment 9

Disinfectants, Deodorants, Fumigants and Cleaning Materials

Collaborating with Joint Committee on Railway Sanitation, AAR

R. S. Glynn (chairman, subcommittee), R. A. Bardwell, R. E. Coughlan, C. E. Fisher, T. L. Hendrix, Jr., H. M. Hoffmeister, R. M. Stimmel, T. A. Tennyson, Jr., A. G. Tompkins, H. W. Van Hovenberg, E. M. Walters, A. B. Pierce.

Your committee submits the following report of progress.

DISINFECTANTS

A prelude to any job of disinfection is thorough cleaning, which in itself removes most of the contamination. The use of a disinfectant is then usually only a "mop-up" operation. Proper cleaning removes most of the unwanted bacteria as well as organic matter, which in many cases interferes with the action of the disinfectant which will follow. When soap is used as the cleaning agent it is germicidal against pneumococci, streptococci and certain other weak organisms, but soap is not germicidal when applied to the more resistant skin organisms.

There are many good cleaner-disinfectant combinations for use on floors, toilet seats, urinals, upholstery, etc., but each individual must select his own product in the light of his possible sources of supply.

In selecting such cleaner-disinfectants several things must be considered, including (a) the supplier, especially his integrity; (b) product claims, and the standing and

reputation of the consulting group doing the tests; (c) service tests, observed and conducted by trained technicians of your own organization; and (d) cost.

Each cleaner-disinfectant should contain a suitable detergent which can be selected by a service test, and an effective disinfectant which has been certified by a reliable testing organization.

A judicial decision made under the original food and drugs acts states, "Language used in the label is to be given the meaning ordinarily conveyed by it to those to whom it was addressed." While it is generally agreed that language is subject to growth and that words acquire new meanings and lose old ones as the years pass, scientific terms are not so flexible as some, yet they also are subject to change according to common usage. Based on a careful study of the literature on the subject, scientific in general, and consultation with bacteriologists, physicians, public health officials, chemical manufacturers and laymen, A. M. Patterson* set forth definitions of several words which reflect present usage, as follows:

Antiseptic—(1) A substance that opposes sepsis, putrefaction, or decay; one that prevents or arrests the growth or action of micro-organisms, either by inhibiting their activity or by destroying them; used especially on agents applied to living tissue. (Patterson, 1932); (2) The representation of a drug in its labeling as an antiseptic shall be considered to be a representation that it is a germicide except in the case of a drug reporting to be, or represented as, an antiseptic for inhibitory use as a wet dressing, ointment, dusting powder or other use as involves prolonged contact with the body (Federal Food, Drug, Cosmetic Act, 1938); (3) Antiseptics are substances which, when applied to micro-organisms, will render them innocuous either by killing them or preventing their growth according to the character of the preparation or the method of application, used especially for preparations applied to living tissue (Reddish, 1927).

These three definitions, although worded somewhat differently, are essentially the same.

Disinfectant—An agent that frees from infection; usually, a chemical agent which destroys disease germs or other harmful micro-organisms (but not, ordinarily, bacterial spores); commonly used as substances applied to inanimate objects (Patterson, 1932).

There is little if any disagreement to this definition. In fact, it is one that has been generally used for many years. However, it is still sometimes misused, such as "skin disinfectant," whereas "skin antiseptic" is more appropriate in describing a germicide for use on the body.

A legal definition for disinfectant is—An agent that frees from infections; usually a chemical agent which destroys disease germs or other harmful micro-organisms or inactivates viruses. Most commonly used to designate chemicals that kill the growing forms, but not necessarily the resistant spore forms of bacteria except when the intended use is specifically against an organism forming spores or a virus, in which case the spores, too, must be killed or the virus inactivated. Proper use of a disinfectant is contingent on the purpose for which employed or the type of infectious agent that there is reason to suspect may be present.

The official definition of the word "disinfection" adopted by the American Public Health Association is—"Killing of pathogenic agents by chemical or physical means directly applied." While most disinfectants are recommended for use on inanimate objects, in some instances antiseptic uses on the body are also specified, but effort is made to encourage elimination of claims for disinfecting as applied to the body and

* Meaning of "Antiseptic", "Disinfectant" and Related Words, American Journal of Public Health, 22, 465–472.

to substitute phrases indicating antiseptic uses instead. Disinfectants should be used only on inanimate objects and claims for such preparations should be made accordingly.

Sanitizer—An agent that reduces the bacterial count to safe levels as may be judged by public health requirements, on food-handling equipment, eating and drinking utensils, and the like.

Use of the word sanitizer should be restricted to connection with cleaning operations in the day-to-day control of the bacterial contamination with equipment and utensils where the complete destruction of all growing forms of bacteria may not be necessary.

Sanitize—To render sanitary. The term conveys the idea of disinfection without any residual harmful to subsequent users of the article or product as well as elimination of any contamination which might be esthetically objectionable.

Sterilizers—A process, physical or chemical, which will destroy all forms of life, applied especially to micro-organisms, including bacterial and mold spores, and the inactivation of viruses.

Sterilization—The act or process of sterilizing, or freeing from all living micro-organisms.

The Council of Pharmacy and Chemistry has formally gone on record as disapproving the use of the terms "sterile", "sterilize", and "sterilization" in a bacteriological sense other than in their correct scientific significance; namely, meaning the absence or destruction of all micro-organisms. These terms are not relative, and to permit their use in a relative sense not only is incorrect but opens the way to abuse and misunderstanding.

The meanings of certain other terms require no clarification or qualification. For example, the suffix "cide" means a killer or destroyer, and the suffix "stat" or "static" means a condition of inactivity or inhibition or, specifically, prevention of growth. The following definitions, therefore, need not be discussed except to indicate specific applications required by common usage.

Germicide or *Bactericide*—Anything that destroys bacteria (micro-organisms); applied especially to chemical agents to kill disease germs, but not necessarily bacterial spores; commonly used for substances applied to both living tissue and inanimate objects.

Fungicide—Anything that destroys fungi; applied especially to chemical agents that kill both pathogenic and nonpathogenic fungi other than bacteria; commonly used for substances applied to both living tissue and inanimate objects.

Viricide—Anything that destroys or inactivates viruses; applied especially to chemical substances used on living tissue.

Sporicide—Anything that destroys spores; applied especially to chemical agents that kill bacterial and mold spores; commonly used as substances applied to inanimate objects.

Preservative—An agent or process that prevents decomposition by either chemical or physical means.

The *phenol coefficient* is a figure attained by dividing the numerical value of the greatest dilution (the denominator of the fraction expressing the dilution) of the disinfectant capable of killing *E. typhosa* in 10 min but not in 5 min, by the greatest dilution of phenol showing the same results.

Whenever an expression of the phenol coefficient occurs in literature on labels, etc., in the United States, it is assumed that *E. typhosa* was used as the test organism; otherwise it should be distinctly designated when stating the phenol coefficient.

Due to its ubiquity, resistance and ever-ready tendency to cause infection, *Staph. aureus* should always be used in testing those substances recommended for personal use or application to wounds. The phenol coefficient method is not well adapted for testing the salts of the heavy metals, the dyes, those compounds containing chlorine as the active agent, or for oxidizing agents in general. The results of phenol coefficient tests can be used for four main purposes: (1) to compare the germicidal activity of the disinfectant with that of clear phenol; (2) to compare the relative germicidal efficiency of different phenol-like compounds, to determine which are best and most economical to use; (3) To indicate the germicidal properties of disinfectants by a single figure for specification purposes and for ease in purchasing by large agencies, such as federal, state, and municipal governments; (4) to use as a means for calculating the effective dilutions for use in practice.

While most bacteriologists interested in the study and testing of disinfectants are fully aware of the limitations of the phenol coefficient as a measure of germicidal activity, it is important that all become fully informed in this regard. Much misinformation has been and still is presented relative to this important subject. Phenol no longer plays any significant role as an anti-bacterial agent, although its use has not been abandoned entirely. Its study aided toward the understanding of the action of the numerous phenol derivatives. The chemical and germicidal properties of many compounds are quite different from those of carbolic acid. The chlorine compounds are unstable and especially so in the presence of organic matter. Phenol is not unstable and is not counteracted by organic matter. A germicidal substance which is counteracted by organic matter, such as the chlorine compounds, should not be compared with a germicide which is not affected by organic matter. Such a comparison is impractical and unscientific. Many antiseptics act in a manner quite different from phenols so that any comparison to the germ killing power of carbolic acid is out of the question.

Bacteriologists have been challenged by limitations of the present methods of testing disinfectants, which do not accurately indicate their real values under the conditions of actual use. Numerous improvements and new technics have been suggested, and doubtless some are superior to the methods now in use. Some authorities doubt the ability of any one technic to provide data applicable under all conditions and suggest that tests may have to parallel the conditions of actual use. Recently, a very excellent suggestion has been made for such a profile evaluation of germicides. A combination of several well-established tests is recommended for the purpose. Use of these tests is specified for determining the following properties of antiseptics: (1) the highest dilution of germicides capable of killing *m. pyogenes var. aureus;* (2) extent of bacteriostassis; (3) influence of organic matter; (4) speed of action; (5) penetrability; and (6) toxicity.

The final criteria for an antiseptic are effectiveness and usefulness in practice. The vast amount of published data supporting the effectiveness of an antiseptic, disinfectant, sanitizer, etc., constitutes sufficient evidence of their value for general use. This extremely important factor should be given first consideration in any study of the properties of antiseptics, disinfectants, sanitizers, etc.

FUMIGANTS

Fumigation as a method of insect and animal control has been known for many centuries. But pest-control operators have, to a large extent, supplanted fumigation with residual sprays, since their use results in long-lasting control without the danger, expense, and inconvenience often attended upon fumigation. Nevertheless, fumigation

is still employed, since it is usually an effective means of ridding a house of vermin, and when used in combination with residual sprays supplies the quick kill often lacking in residual sprays.

Some of the reasons for using fumigation are as follows:

1. Our more commonly used fumigants are toxic to both insects and rodents; thus it is possible by means of one fumigation to control the animal pests in a building.

2. Fumigation is usually the quickest method for controlling animal pests in a building.

3. Fumigants frequently, but not always, kill insects where ordinarily contact or residual and stomach poisons may not reach them, namely, behind baseboard, in hollow spaces in the walls, and in building timbers (dry wood termites).

4. In specific cases, where it may be too dangerous to have poisonous dusts or powders in the vicinity of food, or where sprays may taint such foods with their odors, certain fumigants can be used to kill the pests within or in the vicinity of food.

Some of the reasons why the pest control operator may forego fumigation, preferring some other method of control are:

1. Practically every fumigant that is effective against insects and animal pests is also very toxic to man.

2. Since fumigants are poisonous, special equipment such as gas masks, halide lamps, etc., is required to safeguard the operator against the effect of these fumigants.

3. A building or enclosure must be completely sealed. This necessitates much labor and sealing material.

4. As a rule, the application of fumigants requires more technical skill than other methods of control.

5. Fumigants and the labor factor involved make the initial cost of fumigation comparatively high when compared with other methods of control.

6. It is not permissible for one man alone to fumigate, whereas but one individual need be involved in the application of sprays and dusts.

7. Fumigants may give an almost immediate and complete kill of animal pests, but a new infestation, from outside sources, may commence immediately after the completion of the fumigation.

8. In many cities it is necessary to obtain licenses and to observe many legal restrictions before fumigation may be undertaken.

A great number of volatile organic compounds are sufficiently toxic to be effective as insect fumigants. And, indeed, a considerable variety of compounds have been developed commercially. The first limiting factor is flammability; ethylene oxide, the simple esters, carbon disulfide, and ethylene dichloride require dilution with CO_2 or $C Cl_4$ for safety. The second limiting factor is the toxic hazard to the operator, but this consideration has not prevented HCN from being widely used. It is a disadvantage for the fumigant to be highly absorptive or highly water and fat soluble or absorptive, as are CS_2, HCN. It is advantageous for the gas to be readily desorbed and to leave no residue, as is the case with methylbromide, ethylene oxide, chloropicrin; these vapors are all highly penetrating. It is of course an advantage for the fumigant to be highly insecticidal, although a compound that is as weakly toxic (to insects) as carbon tetrachloride may have its place because of other desirable characteristics. The combination of high volatility with high toxicity is an advantage (namely, HCN, methylbromide, chloropicrin) for the short term fumigation of closed places; but scarcely volatile materials such as naphthaline, p–dichlorobenzene and nicotine have been used successfully, and low vapor pressure materials are preferred as spot fumigants and soil fumi-

gants, (namely; ethylene dibromide, hexachloropropene). One of the main considerations in a choice of fumigants is the cost of the materials and their application.

The elimination of insect infestations in various commodities of commerce is a vital necessity. Enormous losses are caused by insects and other pests, in a wide variety of products such as grain, seeds, dry fruits, cereals and other packaged foods, fresh fruits and vegetables, nursery stock, furniture and textiles. Aside from the danger incurred, pure food laws require that food products be free of insects when offered for sale, and quarantines are placed upon interstate shipment of many types of food or plant products unless they are fumigated prior to or during transit.

Because of its outstanding properties, methylbromide has rightfully become known as the "fumigant of choice" in a space of less than 25 years, and with its use, types of fumigation hitherto difficult or inefficient have become standard procedure. Methylbromide is one of the most toxic fumigants known, and possesses numerous advantages over other materials formerly used. While the action of methylbromide on insects is comparatively slow, the results are positive. There is no survival even though they may appear to be alive after several hours. Some of the advantages of methylbromide are:

(1) High toxicity to a wide range of insects, rodents, etc.

(2) Does not leave residual odors, tastes, or stains.

(3) Kills insects and related pests in all stages or development, including the eggs.

(4) High rate of diffusion and ability to penetrate rapidly into stacked bags, packages, bales, storage grain and soil.

(5) Low solubility in water, permitting fumigation of products with high moisture content, including damp plant materials.

(6) Low boiling point insures rapid volatilization.

(7) Nonflammable and nonexplosive. (See below)

(8) Economical because of low per unit cost in areas to be fumigated.

The fact that methylbromide will kill eggs, larva, pupa and adults of insects is of particular significance, since most fumigants at standard dosages are toxic to adults and larva only. While temperature is an important factor in fumigants, due to its effect on insect activity and metabolism, the effectiveness of methylbromide is not lessened by low temperatures to the extent that it is with some other fumigants. Being an organic solvent, methylbromide should not be used for treatment of furs, leather or rubber goods. Care must be taken to follow directions very closely in fumigating vegetable oils, dairy products, nuts, margarine and other products high in oil content since over exposure can cause darkening or tainting of product.

Fire underwriters consider methylbromide a safe fumigant from the fire and explosion standpoint. The Underwriters Laboratories (list of inspected gas, oil and miscellaneous appliances, December 1940) describe it as "nonflammable over a wide range of concentrations extending far beyond those used in the practice. Flame propagation within a narrow range of 1 percent (13.5–14.5 percent by volume) in the presence of an intense source of ignition is reported in the technical literature. The fire hazard is very small from a practical standpoint."

Though methylbromide is more convenient and less hazardous in many ways than are the more deadly and flammable gases previously used, it is nevertheless toxic to all animal life and humans. Since it is practically odorless and colorless, it should be handled with care and with due respect to surrounding areas that might be affected.

You should comply with all local regulations and post the necessary warning signs where applicable.

Most railroad boxcars are not built sufficiently tight to be used as fumigation chambers, and therefore must be sealed with masking tape or other suitable material in order to prevent the rapid escape of the fumigating gas, but refrigerator cars in good condition are usually satisfactory, if the drains and the hatch covers are sealed prior to fumigation. Methylbromide is introduced through tubing entering through the hatches, one-half the dosage being put through each hatch. An average refrigerator car containing about 2500 cu ft requires 3–5 lb of methylbromide for an exposure of 18–24 hr to treat grain, dried fruit and similar commodities. For fresh produce in the same car a 2–4-hr exposure to 5–6 lb is usually sufficient, depending on the procedure and the temperature conditions. At higher temperatures less methylbromide is required than at lower temperatures. The optimum temperature range being from 65 to 80 deg F. The maximum temperature range for fumigation is approximately 45 to 120 deg F. These limits are established principally by the physiological response of the insect since, being cold blooded, they are almost inactive below 45 deg.

Some precautions to be observed while using methylbromide are as follows:

1. *Do not breathe the vapor of methylbromide.* Wear a gasmask when entering a room or chamber that has been under fumigation, and make certain that no vapors remain. The presence of methylbromide and the approximate amount can be detected readily with a halide leak detector. After fumigation, ventilate cars, rooms, buildings or other chambers before entering.

2. *Avoid spilling the liquid methylbromide on the skin or clothing.* If some is accidentally spilled, get out into the open air immediately and remove all clothing that has been impregnated with the methylbromide. Wash the affected parts of the body with soap and water or with a solution of bicarbonate of soda.

3. Warning signs should always be posted during fumigation, and all entrances sealed and locked.

4. Observe all local, county and state regulations and ordinance. These can usually be supplied by the local agricultural, health or fire department.

5. Store cylinders and cans in a cool place outside of the inhabited building. Be sure that cylinder valves are tightly closed at all times when not in use.

Hydrogen cyanide has been widely employed as a fumigant for buildings and even for citrus trees. Although it has a penetrating odor of bitter almonds it is toxic in such low concentrations that its use requires its mixture with 5 percent chloropicrin or cyanogen chloride as a warning gas. It is flammable only at very high vapor concentrations. HCN is highly adsorptive, which makes it effective at low temperatures, but it also becomes difficult to remove by desorption. In addition, it is readily soluble in water, and hence is highly absorbtive. It may be generated by atmospheric humidity from calcium cyanide and calcium acid cyanide; the commercial powders yield 55 percent of their weight as HCN. It also may be released from cellulosic discoids on which it had been held by adsorption. The traditional method is to drop sodium cyanide into dilute sulfuric acid; it may be weighed into paper or zinc foil bags, or compressed into eggs, 1 lb being dropped into 5 lb of 50 percent H_2SO_4. Higher concentration of H_2SO_4 are liable to hydrolize the HCN into CO and NH_3.

Carbon disulphide is a cheap fumigant handicapped by an unpleasant smell of H_2S. Since it is extremely flammable and explosive, it is diluted with four parts of carbon tetrachloride. Although insoluble in water, it is highly soluble in fatty materials. Carbon disulphide is highly adsorptive and penetrating and is liable to leave yellow

stains. It has proved useful as a soil fumigant and has been employed to fumigate warehouses, dwellings and stored grain.

Carbon tetrachloride is nonflammable, which makes it valuable as a fumigant despite a low insecticidal toxicity. It is often used as a diluent for ethylene dichloride or ethyl acetate. When CCl_4 is employed alone for grain fumigation, a dosage of 30 lb per 1000 cu ft is required. Trichloroethylene constitutes a slightly more insecticidal, non-flammable substitute for carbon tetrachloride.

Acryonitrile is a useful low vapor pressure fumigant for dead spots in flour mills and for bedbug control. Being inflammable it may be mixed with an equal amount of CCl_4 and the mixture proves to be a more effective insecticide than acrylonitrile alone.

Ethylene dichloride has a pleasant chloroform-like odor but is, nevertheless, a self-warning gas. Since it is flammable, three parts of ethylene dichloride are diluted with one part of CCl_4. It is noncorrosive and is used as a mill or domestic type fumigant at 6 lb per 1000 cu ft and may be applied by spraying.

Chloropicrin is a highly insecticidal, self-warning, sweet-smelling lachrymatory gas that has little fire hazard and is highly penetrating. Since it is not water soluble it is not absorbed by foods, and it is not reactive with metals and fabrics. It is used for fumigation of mills, warehouses, and grain at a concentration of 2 lb per 1000 ft; its effectiveness may be enhanced by admixture of CO_2.

Paradichlorobenzene is useful as a soil fumigant and is very widely employed in the form of mothballs to fumigate clothes. Naphthalene has also been employed for the same purposes.

All stages of insects breathe—egg, larva, pupa, adult—but the egg and pupa being physically inactive do not breathe as readily as the larva and the adult, thus as a rule they are not as readily affected by equal concentrations of gas as are the larva and the adult. Carbon dioxide exhilarates the rate and amplitude of respiration in insects as well as in warm-blooded animals, and is believed to affect the tracheal valve control in insects, and for this reason carbon dioxide is mixed with a number of fumigants.

Report on Assignment 10

Railroad Aspects of Radioactive Substances

Collaborating with Joint Committee on Railway Sanitation, AAR

R. O. Bardwell (chairman, subcommittee), R. C. Bardwell, V. C. Barth, Jr., J. M. Bates, C. E. Fisher, R. S. Glynn, T. W. Hislop, Jr., J. J. Laudig, J. P. Rodger.

During the past year, several railroads in the United States have used radioactive piston rings to measure the rate of piston ring wear in diesel locomotives. These tests have proved to be extremely fruitful. They have been used to measure the effect of various fuel oils, lubricating oils, and engine components on piston ring wear.

The radioactive piston rings are obtained by placing standard piston rings in a nuclear reactor for several weeks. Exposure to the neutrons in the reactor causes some of the iron in the rings to become radioactive.

The radioactive rings are then installed in a locomotive engine in the railroad shops and the locomotive placed on static load test. The rate of wear of the radioactive rings is then determined by measuring the rate of accumulation of radioactive iron in the engine lubricating oil.

The determination of the wear rate for a fixed set of conditions, i.e., load, fuel oil and lubricating oil, requires about 6 hr. The sensitivity of the measurement is such that a wear rate of a ten-billionth of an inch per hour can be measured within a few percent. It is this sensitivity which allows information to be gained in one or two days which would take several years by conventional wear measurements.

The hazards involved in performing these tests are extremely small. It has been the experience of the railroads using the radioactive measuring technique that no person has been exposed to as much as one-fifth of the allowable radiation tolerance dose. This can be stated in another way by saying that during the several months that these tests have been run, no person has received as much radiation as he would from a single chest X-ray.

In order to make the test as sensitive as possible, fresh lubricating oil is used for each days' test. Since the lubricating oil is used for only one day in the test engine, the amount of radioactive iron it contains is very small, less, in fact, than the allowable concentration for drinking water. Because of this, the lubricating oil may be filtered and used in normal locomotive service on the railroad.

After the series of wear measurements has been performed, the radioactive rings must be removed from the engine before it can be returned to normal service. The rings are then sent to a licensed, radioactive disposal firm.

The experience of the railroads using the radioactive wear measurement technique has established that useful and otherwise unobtainable information can be obtained without any appreciable hazard.

This report is presented as information.

Report on Assignment 11

Methods of Heating Fuel Oil to Permit Winter-Time Use of High-Pour-Point "Economy" Grade Fuel Oil

C. E. DeGeer (chairman, subcommittee), R. A. Bardwell, P. J. Calza, D. E. Drake, C. E. Fisher, E. M. Grime, H. M. Hoffmeister, C. O. Johnson, G. F. Metzdorf, John Norman, N. B. Roberts, E. O. Salners, C. B. Voitelle.

The testing facility mentioned in last year's report has now been completed. It consists of a 25,000-gal above-ground tank covered with 2 in of insulation having a "k" factor of 0.25, which, in turn, is covered with 0.025-in aluminum sheeting. This gives a certain degree of reflective insulation and does not need any painting maintenance.

The tank is heated by three electric heaters totaling 18 kw, providing 1.1 w per sq in of heating surface. The electrical input is metered, and a two-pen thermometer (one pen for outside temperature and one pen for the oil temperature in the tank) has been installed. The plant attendant notes on the recorder chart the temperature and number of gallons unloaded and the gallons of oil in the storage tank each time a tank car of oil is unloaded.

With these knowns, i.e., the temperature of the oil and the number of gallons in the storage tank, temperature and gallons of oil unloaded, outside temperature, "k" factor of the insulation, amount of electricity used, and the cost of the power, it is believed that the cost of heating fuel oil can be obtained by the spring of 1959 after the test tank has been in operation. It is located where the mean temperature for January and February is approximately 0° F.

This progress report is presented as information.

Report of Committee 14—Yards and Terminals

F. A. Hess, *Chairman,*
A. S. Krefting,
Vice Chairman,
H. L. Scribner, *Secretary,*
M. H. Aldrich
J. D. Anderson
F. E. Austerman
R. O. Balsters
R. F. Beck
A. E. Biermann
W. O. Boessneck
W. S. Broome
W. P. Buchanan
G. H. Chabot
H. P. Clapp
K. L. Clark
B. E. Crumpler
J. L. Dahlrot
A. V. Dasburg
Oscar Fischer
H. C. Forman
S. W. George
W. H. Giles
W. H. Goold
H. J. Gordon
J. E. Griffith
C. A. Hagen
G. F. Hand (E)
D. C. Hastings
Wm. J. Hedley
H. W. Hem
J. E. Hoving
V. C. Kennedy
B. Laubenfels
Glen Lichtenwalner
J. L. Loida
E. T. Lucey
L. L. Lyford (E)
S. N. Mac Isaac
G. W. Mahn, Jr.
H. J. McNally
J. C. Miller
R. F. Moris
C. J. Morris
C. H. Mottier
A. G. Neighbour
B. R. Nelson
B. G. Packard
C. F. Parvin
R. H. Peak, Jr.
G. A. Peirce
Hubert Phypers
L. F. Pohl
W. H. Pollard
G. L. Roberts
L. W. Robinson
R. E. Robinson
H. T. Roebuck
M. S. Rose
H. H. Russell
W. C. Sadler
L. R. Shellenbarger
R. A. Skooglun
F. R. Smith
R. F. Straw
A. L. Thurston
J. N. Todd
C. W. Traister
P. P. Wagner, Jr.
W. E. Webster, Jr.
C. F. Worden
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Report on Water-Front Terminals, with the recommendation that it be adopted and included in the Manual ..... page 290

2. Classification yards, collaborating with Committee 16.

   Progress report on determination of rollability of cars being conducted by AAR Joint Committee on Relation Between Track and Equipment, AREA Committee 14 collaborating ..... page 291

3. Scales used in railway service, collaborating with Electrical Section, AAR.

   No report.

4. Use and location of yardmasters' offices.

   Final report, presented as information ..... page 292

5. Influence of roller bearing cars on design of hump and flat yards.

   No report.

6. Facilities for loading and unloading rail-truck freight equipment.

Progress report, presented as information ..... page 293

7. Parking facilities for patrons at passenger stations.

Final report, presented as information ..... page 294

8. Use of car retarders at locations other than on a hump.

Final report, presented as information ..... page 298

THE COMMITTEE ON YARDS AND TERMINALS,
F. A. HESS, *Chairman.*

AREA Bulletin 546, November 1958.

Report on Assignment 1

Revision of Manual

F. E. Austerman (chairman, subcommittee), A. E. Biermann, B. E. Crumpler, H. C. Forman, W. H. Giles, Wm. J. Hedley, F. A. Hess, J. E. Hoving, L. L. Lyford, H. J. McNally, C. H. Mottier, R. E. Robinson, J. N. Todd, P. P. Wagner, Jr.

Your committee offers the following report with the recommendation that it be adopted and published in the Manual as a continuation of the material on Freight Terminals, Part 3, Chapter 14.

I. WATER-FRONT TERMINALS

1. General

A water-front terminal provides facilities for the transfer of shipments or cargoes from ship or barge to railway cars or trucks, and from railway cars or trucks to ship or barge. The facilities consist of docks, wharves, piers and warehouses, with loading and unloading equipment and necessary railway tracks and roadways for transfer purposes.

The waterside may be an ocean, lake or river, but is usually a harbor on one of these. A dock is the facility at which ships are moored. A dock may be parallel to the shore line, in which case it is called a wharf. If a dock is built at an angle ranging from acute to right to the shore line, where ships can be moored on both sides, the structure is called a pier. Wharves and piers may be open or covered, depending on the protection needed for the commodity handled. Some piers are used for short-term storage as well as the transfer of goods.

In designing a water-front terminal consideration must be given to the type and quantity of freight to be handled, and to the trackage and track arrangement required so that proper switching to and from docks can be provided. The facilities on land are provided to economically load and unload commodities. Docks should also be equipped with necessary conveyors, pipelines, car dumpers, cranes, hoppers and any other facility necessary to handle special commodities.

Large structural cranes may be built over docks to extend over ships to facilitate the handling of loads. Conveyor systems may be built to move commodities in bulk or in units. Some important docks specialize in handling one commodity, such as ores, coal, grains, fruit (bananas), automobiles or equipment, or to transfer railway cars and certain merchandise.

Wharves may be served by tracks parallel to the wharf. Occasionally wharves are equipped with tracks constructed adjacent to the water's edge, and goods are handled directly between the ship and railway cars.

Piers are usually provided with tracks running down their center or along the edge. Transfer bridges are used for handling railway cars to and from ships, car floats or ferries.

Various yards for railway cars are a part of a water-front terminal. A storage yard is usually necessary for cars held for loading or unloading and to accumulate special cars for a particular ship. A classification yard, with or without receiving and departure yards, storage and car repair yard, may be provided, depending upon the volume of traffic handled.

Adequate storage space—ground pier or covered warehouse—is essential for commodities awaiting shipment. The arrangement of these yards and storage space is important so there will be the minimum of interference in handling cars to and from the yards and unloading spots.

Report on Assignment 2

Classification Yards

Collaborating with Committee 16

Rollability of Cars

F. R. Smith (chairman, subcommittee), H. P. Clapp, A. V. Dasburg, F. A. Hess, A. S. Krefting.

Your committee submits the following progress report as information on the rollability of cars.

In 1957, Committee 14 recommended a joint effort on the part of the American Railway Engineering Association and the Mechanical Division of the Association of American Railroads to determine:

1. Rolling resistance of freight cars under a variety of conditions.
2. Potential improvements in the track and the freight car to reduce widespread variation in rolling resistance among cars and in the same car as it rolls along the track under varying conditions.

The objective of the proposal was to investigate what might be done for better car control to reduce expensive car damage, lading damage, delays, per diem, yard cleaning, and crew time in switching operations and at loading or unloading facilities where cars are moved under the influence of gravity.

As a result of this recommendation, the subject was assigned to the Joint Committee on Relation Between Track and Equipment, AAR. In 1958, $3000 was appropriated for engineering research in connection with this assignment. This money was used to obtain some of the data now available on rolling resistance from the railroads and other related industries in the United States and Canada.

Two questionnaires have been prepared and circulated at the request of Committee 14 and the Joint Committee. One questionnaire, prepared for Engineering Division Research, was sent to chief engineers, while the second, prepared for Mechanical Division Research, will be answered by chief mechanical officers.

The Engineering Division questionnaire requested copies of rolling-resistance data with the conditions under which the data were obtained. The Mechnical Division questionnaire was primarily related to equipment factors that probably influence variation in rolling resistance with a request for data and opinion pertaining generally to:

1. Lubrication of truck center and side bearings and a design using rust-resisting materials.
2. Effect of brake rod eccentricity and its relation to rolling resistance and derailments.
3. Device for freeing brake shoes when air is bled out of car and hand brake released.
4. Longitudinal translation of truck side frames caused by tolerances in truck bolsters, journals, etc.
5. Differences in weights of wheels and axles.

Each questionnaire requested an opinion or actual data on the cost of car and lading damage per year and the total number of cars handled in the yard where this damage occurred.

After the information from both questionnaires has been received and summarized, decisions will be made relative to such physical research as may be needed for both track and cars.

Report on Assignment 4

Use and Location of Yardmasters' Offices

R. H. Peak (chairman, subcommittee), A. E. Biermann, H. C. Forman, S. W. George, J. E. Griffith, C. A. Hagen, D. C. Hastings, F. A. Hess, J. E. Hoving, A. S. Krefting, B. Laubenfels, G. Lichtenwalner, J. L. Loida, S. N. Mac Isaac, J. C. Miller, C. J. Morris, B. G. Packard, M. S. Rose, W. C. Sadler, L. R. Shellenbarger, C. W. Traister, W. E. Webster, Jr.

Your committee submits as information the following report of current trends in the use and location of yardmasters' offices, with the recommendation that the subject be discontinued.

Information was received relative to 35 recently constructed or currently planned yard offices on 14 railroads. Of these, 13 are at hump yards and 22 at flat yards.

The preponderant trends noted in these new offices are the increased use of the tower type, and a continued increase in the amount and variety of communications equipment provided.

Of the 35 new offices, only 10 are at track level; 2 of these are at hump yards and 8 at flat yards. One of the ground-level hump yard offices places the yardmaster at the ground level but puts the hump conductor in a tower 16 ft above the top of rail. Tower floor elevations vary from 12 to 50 ft, with the majority in the 25 to 35-ft range. Several of those reporting higher towers indicated that some obstruction to the view dictated the unusual height. In planning a tower, consideration must be given to the downward view of nearby activities as well as the distant view.

Most of the offices are located at the throat of the yard, with a scattering further along the ladder track or opposite the body of the yard. All of the offices have telephones; most of them have radio and yard speaker arrangements. About half have teletype and pneumatic tube installations. Six of the new offices have television; these are all at hump yards and are used for recording car numbers on cuts. The use of

television as an aid to the yardmaster in generally overseeing the yard activity has been considered but the committee knows of no location where it has been permanently installed or where such installation is definitely planned. Since the object of the tower construction is to give the yardmaster an over-all view of the yard operation, this same objective might be accomplished by strategically placing television cameras.

In most cases the offices contain space for yard clerks, at ground level, and wash and locker facilities. Four have the scale recorder mechanism, five have lunch rooms, and eleven have space for other departments and personnel. A feature in some of the lunch rooms is a battery of coin-operated machines dispensing hot and cold foods and beverages.

The general arrangement of a one-story building for yard clerks and other uses, supplemented by a tower of desired height to place the yardmaster in the best viewing position, is the most widely used. In some cases a multi-story building has been built having the yardmaster on the top floor, with the clerks, other departments, wash and locker rooms, lunch rooms, etc., occupying the other floors. In all cases where the yardmaster is elevated above ground level, his office is almost completely glass enclosed to provide a clear view in every direction.

Report on Assignment 6

Facilities for Loading and Unloading Rail–Truck Freight Equipment

C. F. Parvin (chairman, subcommittee), J. D. Anderson, W. O. Boessneck, W. S. Broome, C. H. Chabot, K. L. Clark, Oscar Fischer, S. W. George, H. J. Gordon, Wm. J. Hedley, F. A. Hess, J. E. Hoving, B. Laubenfels, E. T. Lucey, S. N. Mac Isaac, G. W. Mahn, Jr., H. J. McNally, R. F. Moris, B. G. Packard, R. H. Peak, Jr., G. L. Roberts, L. W. Robinson, M. S. Rose, W. C. Sadler, P. P. Wagner, Jr.

This report is submitted as information with the recommendation the subject be continued. Previous reports on this subject may be found in Vols. 56, 57 and 59 of the Proceedings.

As indicated in the report made in 1958, there is increasing use of, and interest in, unit containers and trailer bodies which can be removed from the truck chassis of a flat-bed trailer and transferred to railroad cars.

One method of handling truck bodies, or containers, is by traveling gantry crane. The truck–trailer unit is driven under the crane and the truck body, or container, is transferred to or from the railroad car.

The crane must span the road and adjacent tracks being used for this service, but will eliminate the need for fixed or portable ramps and turning areas at the ends of such ramps. Also, inbound shipments need not be headed in a specific direction on arrival for unloading. Loading and unloading can be done in any desired order.

Moving the truck body directly to or from flat cars and truck or trailer chassis presents two items for consideration.

One such method requires the truck body to be centered over the flat car and at right angles to it during the loading and unloading process. This means the truck body will extend over the sides of the flat car during this period and will require sufficient clearance from the adjacent track.

When the tractor is used as a power unit during the transfer it is important that a proper roadway be provided within the limits of the general area where the tractor

is performing this work. This heavy-duty roadway should begin approximately 12 ft from the near rail of the track, be 18 ft in width and parallel to the track.

Side loading and unloading of trailer bodies directly between flat car and trailer chassis is being developed. The present method utilizes a trailer-mounted transfer unit parked next to the trailer body being transferred. The trailer, or container units, transfer unit and chassis are all special equipment. The transfer can be made to any standard flat car.

Report on Assignment 7

Parking Facilities for Patrons at Passenger Stations

L. F. Pohl (chairman, subcommittee), F. E. Austerman, A. E. Biermann, W. O. Boessneck, H. J. Gordon, C. A. Hagen, Wm. J. Hedley, F. A. Hess, S. N. Mac Isaac, G. W. Mahn, Jr., H. J. McNally, C. J. Morris, A. G. Neighbour, B. G. Packard, C. F. Parvin, G. L. Roberts, C. W. Traister.

This is a final report submitted as information with the recommendation that the subject be discontinued.

The continuing increase in the use of automobiles is producing a corresponding increase in the need for providing enlarged parking facilities. Municipalities, businesses and industries, including the railroads, are confronted with the problem. Its solution rests essentially with the municipality and should be handled by or under the supervision of the municipality, because a successful accomplishment is directly related to the degree of policing of the parking lot and adjacent areas.

Adequate parking facilities at passenger stations are related to:

1. Short-term occupancy for private automobiles awaiting train arrival or departure.
2. All-day parking or shift occupancy for patrons who park their cars during daily working hours.
3. Long term occupancy for patrons who may wish to park their cars for several days while they are away on trips.

In some instances a completely integrated layout may include holding space for taxicabs, for loading and unloading busses, and for rent-a-car agencies.

Where adequate patron parking facilities are lacking, it is common practice for railroads to lease their vacant property to the municipality, community organizations, or to concessionaires for parking-lot development. The lease agreements generally provide that all improvements shall be made by the lessee who shall also be responsible for the operation of the lot. For the use of its property the railroad may receive a fixed rental or a percentage of the gross receipts varying from 10 to 35 percent or more, depending upon local circumstances. This arrangement is a desirable one since the railroad is relieved of the initial construction cost, recurring maintenance expense, liability insurance premiums, and policing costs.

At some locations where parking is not extensive and can be limited strictly to railroad patrons, the railroads may furnish the parking facilities and make no charge or only a nominal charge for parking privileges. In congested areas where the land and development costs are high and the commuter parking lots are operated as private enterprises, the parking rates for a 12-hr period may vary from 25 cents to $1.50, with most falling within the 40- to 60-cent range.

Design details are available in recently published reference books, which include:

Parking, 1957 edition, by R. H. Burrage and E. G. Mogren, Eno Foundation.
Traffic Design of Parking Garages, 1957 edition, by E. R. Ricker, Eno Foundation.
Parking Guide for Cities, 1956 edition, Bureau of Public Roads, Washington 25, D. C.
Data Book for Civil Engineers—Design, by E. E. Seelye.
Traffic Quarterly—January 1954 issue contains a cumulative index 1947 through 1953.

The following general comments are presented for guidance in developing passenger station parking facilities or in evaluating existing facilities for the purpose of planning extensions or improvements.

The principal design factor is location—nearness to the passenger station as well as convenience of access to existing public thoroughfares. The general layout of a parking lot will depend on the size and shape of the available area. Consideration must also be given to the following factors:

Geometric Layout

The basic unit space should measure 8 ft 0 in. in width and 18 ft in length for driver parking. The angle of parking relative to the approach aisle may vary from 30 to 90 deg, the choice depending largely upon the size and shape of the available area. The more acute the angle of parking, the greater will be the proportion of space wasted. Where space is available for a wide aisle, 90-deg parking can be arranged to advantage.

Fig. 1 shows the normal requirements for space and aisle widths for various parking angles. The arrows indicate direction of movement on entering or leaving a given space. One-way traffic is shown for all parking angles except the 90-deg scheme where movements can be made in either direction with equal facility. Either back-in or head-in parking may be used in 90-deg lots. For angle parking at less than 90 deg, head-in parking is more common and generally results in safer and smoother operation. Space may be conserved by using a herringbone or interlocking arrangement of spaces for angle parking, but this advantage may be offset by the cost of barriers required to protect the sides of automobiles from damage.

Fig. 2 shows a commuter parking lot constructed in 1956 at an intermediate station adjacent to Chicago. Space is provided for parking 271 cars and, in addition, room is provided for taxicab stands, bus turnaround, and temporary standing space for private cars. The development costs, exclusive of cost of land, averaged $250 per parking space.

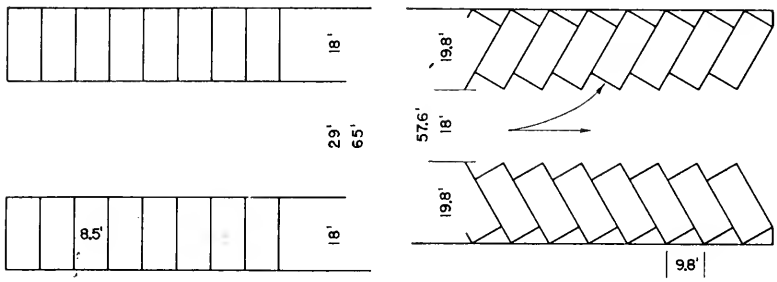
Arrangement of Entrances and Exits

Parking lot entrances and exists should be well defined and should be planned to eliminate interference with street traffic so far as possible. Entrances should be located close to the station or train loading point so that this portion of the lot will be first available. Reservoir space at entrances and exits should be provided to prevent back-ups into the traffic lanes.

Method of Operation

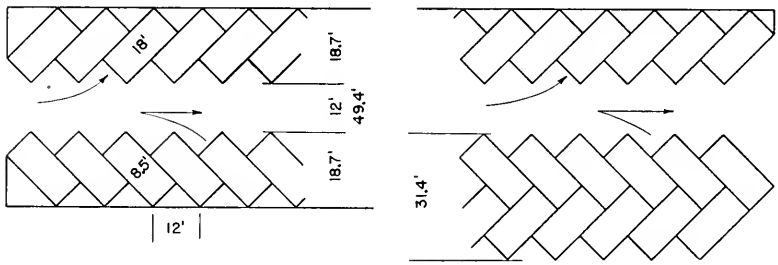
The layout can be planned for attendant-parking or driver-parking. Each method has distinct advantages and the choice will depend upon local conditions.

Parking fees can be collected by an attendant—by selling monthly windshield stickers, by the honor system (fee placed in a collection box) or by using mechanical devices. Parking meters cost approximately $60 each and are relatively expensive to service.

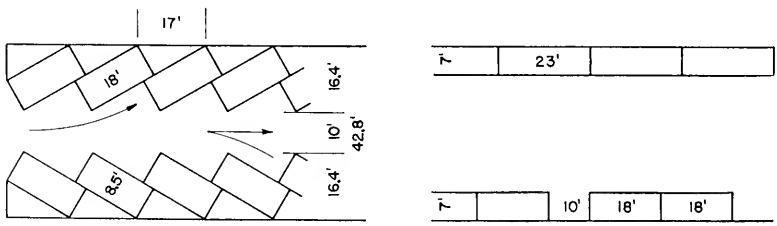


90° PARKING

60° PARKING



45° PARKING



30° PARKING

PARALLEL PARKING

FIG. I RECOMMENDED STALL AND AISLE DIMENSIONS

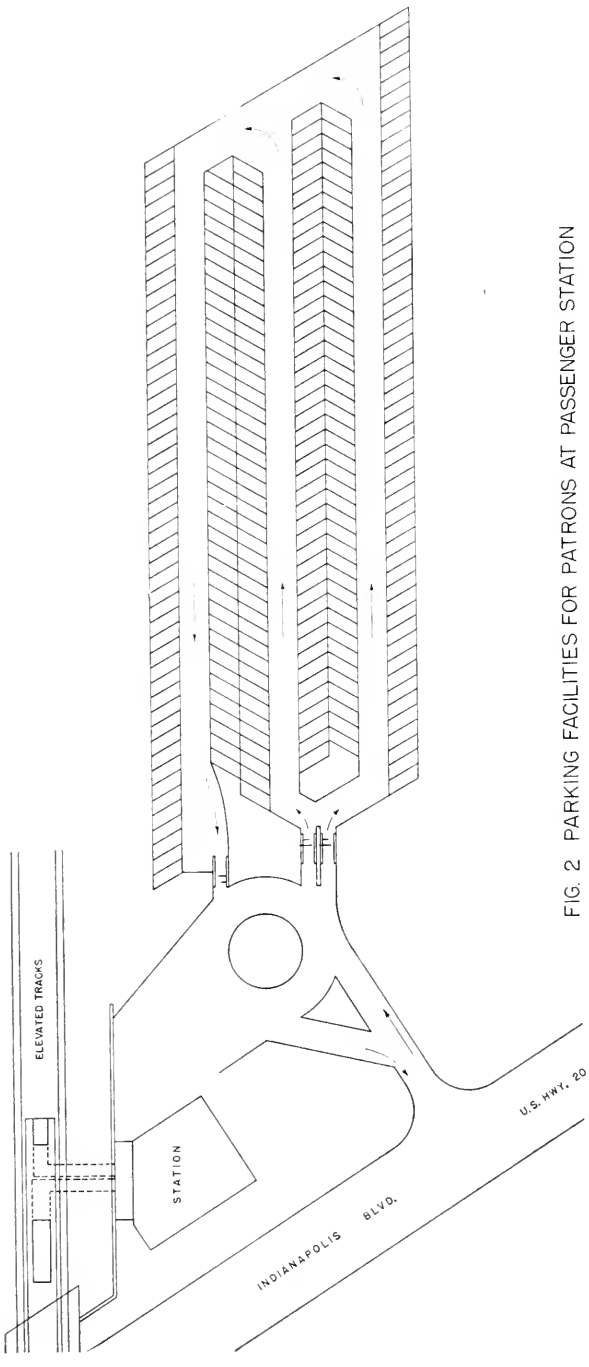


FIG. 2 PARKING FACILITIES FOR PATRONS AT PASSENGER STATION

Many of the recently constructed parking lots use toll gates for collecting the parking fee. The collection unit is controlled by a coin-operated mechanism; the non-pay unit is controlled by a treadle or magnetic pickup. Coded pass cards or keys can be supplied to provide weekly or monthly parking rates to regular patrons if desired. The cost of a toll gate is approximately $1500 installed. This type of installation seems to be best adapted for use at passenger station parking lots. Multiple installations should be made to avoid a tie-up in case of mechanical failure.

Drainage and Paving

Drainage, grading, and surface treatment for dust prevention should be provided. Bituminous paving is generally used, with the unit parking spaces delineated by lines painted on the pavement.

Lighting and Enclosure

Adequate lighting and suitable enclosure are desirable for safe operation of the parking lot and to prevent pilfering and vandalism.

Local Zoning Restrictions

Local zoning ordinances may include requirements or restrictions pertaining to curb cuts and driveway entrances, set-backs, fencing, and landscaping.

Parking Garages

The providing of parking garages for patrons at passenger stations is not common. For economic reasons, their use is limited to areas of high commercial development where vacant land is not available for parking lots. Multi-level structures require the use of ramps or hoists to provide access to the various floors.

Report on Assignment 8

Use of Car Retarders at Locations Other Than a Hump

G. H. Chabot (chairman, subcommittee), M. H. Aldrich, R. F. Beck, H. P. Clapp, K. L. Clark, B. E. Crumpler, A. V. Dasburg, H. C. Forman, W. H. Goold, J. E. Griffith, F. A. Hess, A. S. Krefting, G. Lichtenwalner, S. N. MacIsaac, R. F. Moris, A. G. Neighbour, L. F. Pohl, W. H. Pollard, L. J. Riekenberg, L. W. Robinson, H. T. Roebuck, W. C. Sadler, H. L. Scribner, L. R. Shellenbarger, W. E. Webster, C. F. Worden.

Your committee submits the following report on the use of car retarders at locations other than a hump as information, with the recommendation that the subject be discontinued.

Car retarders in the past have been located primarily at the hump end of classification yards. Within recent years these devices have had more diversified applications, their use has expanded to various locations in yard tracks and in tracks serving private concerns.

By definition, a car retarder is "a braking device, usually power-operated, built into a railway track to reduce the speed of cars by means of brake-shoes which, when set in braking position, press against the sides of the lower portion of the wheels." (Glossary, AREA Manual). With the development of two general types of car retarders, this definition should be expanded to include the *operated* (controlled) retarders and the *inert* (fixed) retarders.

The operated car retarder is an energized braking device that applies a variable or fixed pressure against the car wheels to control car speed; the inert car retarder is a non-releasable braking device that applies a constant predetermined pressure against the car wheels to limit car movement. Retarders located at a hump would generally be of the first type, while retarders at other locations could be of either type.

At points other than a hump some uses of car retarders are still in the experimental stage. The type, number of units and location vary with local conditions. Some of the factors that control the use of retarders are track gradients, type and number of cars handled, problem to be solved, or special situations. Table 1 contains a partial list of retarders at locations other than at a hump.

Some of the practical applications and their benefits are:

1. Departure end of classification tracks in hump yards:
   a. avoids side-swipe damage to equipment and lading where cars tend to run out of body tracks,
   b. prevents over-run of clearance point,
   c. eliminates riders or skatemen.
2. In flat yards:
   a. limits travel of car,
   b. increases efficiency of engines by eliminating necessity to hold on to cut of cars.
   c. minimizes damage to lading by preventing excessive impacts,
   d. eliminates grade revision,
   d. eliminates riders or skatemen,
3. On approaches to scales:
   a. reduces car speed for proper weighing,
   b. permits motion weighing,
   c. aids in pulling pins.
4. Beyond scales where motion weighing is performed:
   a. decelerates cars to a safe coupling speed,
   b. prevents run-outs,
   c. gathers cars for further handling.
5. On car repair tracks and miscellaneous yard tracks:
   a. stops car at a specific location,
   b. expedites operation.
6. At coal, ore, cement, pulpwood and other dumping locations, such as at barney pit, on top of dumper and at loading points:
   a. stops and retains car at point to be pushed,
   b. stops and holds car at point to be dumped,
   c. retards car at loading point.
7. On return track from dumper:
   a. reduces speed of car from kickback,
   b. lessons impact of empty cars.
8. Below loading point ahead of storage yard:
   a. reduces speed of car from loading point,
   b. lessons impact.
9. On certain industrial tracks:
   a. increases efficiency of operation,
   b. reduces impacts.

TABLE 1—CAR RETARDERS AT LOCATION OTHER THAN A HUMP

Location	Concern	Traffic		No. of Tracks	Retarder		Operation
		Load	Empty		Operated	Inert	
Ashtabula, Ohio	NYC	X		1	X		Car dumping
Atlanta, Ga.	Southern	X	X	65	X		Classification tracks
Braddock, Pa.	U. S. Steel Corp.		X	5	X		Car dumping
Bridgeport, Ala.	TVA		X	1			Car dumping
Calhoun, Tenn.	Bowaters Sou. Paper	X		2	X		Pulpwood dump
Chicago, Ill.	C&O	X	X	13		X	Classification yd
Chicago, Ill.	Commonwealth Edison		X	4	X		Car dumping
Chiquamata, Chile	Chile Express Co.			4	X		Car dumping
Conneaut, Ohio	Pitts.-Conneaut Dock	X	X	8	X		Car dumping
Corbin, Ky.	U. S. Steel Corp.	X	X	1	X		Car dumping
Dante, Va.	Clinchfield Coal	X	X	8	X		
Flint, Mich.	C&O	X	X	8		X	Classification tracks
Flint, Mich.	C&O	X		1		X	Scale track
Gallatin, Tenn.	TVA		X	1	X		Car dumping
Gary, Ind.	Universal Atlas Cement		X	1		X	Car dumping
Hammond, Ind.	St. Line Gen. Co.		X	5	X		Car dumping
Havana, Ill.	C&IM	X	X	3	X		Car dumping
Hayne, S. C.	Southern			4	X		Car repair shop
Hudson, N. Y.	Atlas Cement Co.	X		1	X		Car dumping
Huron, Ohio	W&LE			8			Car dumping
Jackson, Miss.	IC	X		1	X		Scale track
Jersey City N. J.	CRR of NJ	X	X	5	X		Car dumping
Kingston, Tenn.	TVA		X	2	X		Car dumping
Lorain, Ohio	B&O	X	X	5	X		Car dumping
Ludington, Mich.	C&O	X	X	5		X	Classification tracks
Mahanoy City, Pa.	P. & R. C. & I. Co.	X		1	X		Car dumping
McClound, Tenn.	TVA		X	1	X		Car dumping
Morisville, Pa.	U. S. Steel Corp.			4	X		Car dumping
Newport News, Va.	C&O		X	12	X		Car dumping
Paducah, Ky.	TVA		X	1	X		Car dumping
Pueblo, Colo.	C&W	X	X	1		X	Billet mill
Puerto Ordaz, Ven.	Orinoco Mining	X	X	4	X		Car dumping
Sandusky, O.	Pennsylvania	X	X	5	X		Car dumping
Seven Islands, Que.	Iron Ore. Co. of Canada	X		1	X		Car dumping
Toledo, Ohio	C&O		X	12	X		Car dumping
Toledo, Ohio	LFD&RRT	X		1	X		Car dumping
Toledo, Ohio	NYC		X	12	X		Car dumping
Waukegan, Ill.	Waukegan Gen. Co.		X	2	X		Car dumping
Wilcoe, W. Va.	U. S. C. & C. Co.	X	X	8	X		Car dumping
Youngstown, Ohio	U. S. Steel Corp.	X		1	X		Car dumping

Report of Committee 20—Contract Forms

E. M. Hastings, Jr.
Chairman,
D. F. Lyons,
Vice Chairman,
A. F. Hughes, *Secretary,*

J. J. Baffa
G. H. Beasley
K. A. Begemann*
H. F. Brockett
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W. D. Kirkpatrick
J. S. Lillie (E)
L. W. Lindberg
W. J. Malone
W. L. Mogle
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W. G. Nusz (E)
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E. E. Phipps
C. M. Sherman
K. J. Silvey
W. R. Swatosh
J. W. Wallenius
D. J. White
D. H. Yazell
Clarence Young
H. L. Zouck

Committee

* Died August 15, 1958.
(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, with recommendations submitted for adoption ..... page 302

2. Form of lease covering the use of railway tracks for storage of tank cars containing liquefied petroleum gases, anhydrous ammonia, and other flammable or dangerous materials, collaborating with the Fire Protection and Insurance Section, AAR.
   Progress report, submitted as information ..... page 304

3. Form of lease covering right to strip mine on railway miscellaneous physical property.
   Brief progress statement ..... page 308

4. Form of agreement covering parallel occupancy of railway right-of-way property by electric power lines.
   Submitted for adoption and publication in the Manual ..... page 308

6. Form of agreement for construction and maintenance of highway–railway grade separation structures for public roads.
   Progress report presented as information ..... page 308

The Committee on Contract Forms,
E. M. Hastings, Jr., *Chairman.*

Report on Assignment 1

Revision of Manual

W. R. Swatosh (chairman, subcommittee), K. A. Begemann, A. B. Costic, G. K. Davis, C. L. Gatton, J. F. Halpin, E. M. Hastings, Jr., R. C. Heckel, W. D. Kirkpatrick, J. S. Lillie, O. K. Morgan, W. G. Nusz, G. W. Patterson, Clarence Young.

Your committee offers the following recommendations with respect to the Manual:

Delete from the Manual "Form of Agreement to Permit Subsurface Exploration by State or Other Governmental Agencies on Railway Right-of-Way", pages 20–7–8, and 20–7–9, and replace with the revised form entitled "Form of Agreement to Permit Subsurface Exploration on Railway Property" presented herewith.

The text of the revised form, in essence, is similar to the existing form but includes under "Notes" an alternate Sec. 4. Indemnity, and a Sec. 4 (a). Insurance, to cover the preparation of an agreement with an agent of a Governmental body, a private party, or a corporation, thus widening the application of the form.

FORM OF AGREEMENT TO PERMIT SUBSURFACE EXPLORATION ON RAILWAY PROPERTY

THIS AGREEMENT, made this ..... day of ....., 19 ....., by and between the ....., with its principal office at ....., hereinafter referred to as the Railway Company and the ..... hereinafter referred to as the .....

WITNESSETH:

WHEREAS, the Railway Company is the owner of certain lands in the Township of ....., County of ....., State of ....., and

WHEREAS, for the purpose of ascertaining subsoil conditions, the ..... is desirous of making certain borings on the property of the Railway Company located at ....., in the Township of ....., County of ....., and State .....;

NOW, THEREFORE, in consideration of the covenants herein contained, the parties hereto mutually agree as follows:

1. Grants

The Railway Company hereby grants authority to the ....., to enter upon its property, after 48 hours notice, to drill and make such borings in such manner and at such locations as may be agreed upon between the ..... and the Chief Engineer of the Railway Company.

2. Protection

The ..... shall exercise all reasonable care and shall take such precautions as the Chief Engineer may deem necessary to properly protect the Railway Company's facilities and operations. The Railway Company reserves the right to place watchmen, flagmen, inspectors and supervisors for protective purposes during such boring operations, and the expense thereof, including the expense of any material furnished, shall be promptly paid by .....

upon receipt of Railway Company's bill therefor. In addition to direct wage and material cost, such expense shall include, but shall not be limited to, cost of supervision, traveling expenses, Federal Railroad Retirement and Unemployment taxes, vacation allowances and all other expenses incidental thereto.

3. Data

The ..... shall furnish to the Chief Engineer of the Railway Company, without charge, a copy each of the boring layout and test boring log.

4. Indemnity (See Note)

The ..... shall indemnify the Railway Company and save it harmless from all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out of injury to or death of any person or persons, or damage to or destruction of property of any person whomsoever, in connection with the work herein contemplated, and operations adjacent or incident thereto, arising in any way out of the performance of the work for which the permission herein is granted.

5. Restoration

Upon completion of the work, the ..... shall restore the premises to their original condition, or a condition satisfactory to the Chief Engineer of the Railway Company.

6. Termination

This agreement shall automatically terminate and shall be considered cancelled ..... from the date first hereinbefore written; provided, however such termination shall not be construed as relieving the .... of any obligations or liability incurred prior to such termination.

7. Assignment

The covenants, terms and agreements herein contained shall be binding upon and inure to the benefit of the parties hereto and their respective successors and assigns.

8. Successors

This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors and assigns.

In Witness Whereof, the parties hereto have executed this Agreement in .... on the day and year first above written.

Railway Company

.....

Witness: ..... By .....

.....

Witness: ..... By .....

Note 1:—It is recommended that the above form be used when Agreement is made with State or other Governmental agencies.

Note 2:—In the event that the Agreement is made with a private party, a cor-

poration or an agent of a Governmental body, the following "Indemnity" and "Insurance Provisions", designated Sec. 4 and Sec. 4 (a), respectively, should be substituted for the foregoing Sec. 4. Indemnity:

4. Indemnity

The ..... agrees to provide insurance to release, indemnify, protect and save harmless the Railway Company from and against any and all loss of life or property, or injury to the person or loss or damage to the property of any person, firm or corporation (including the parties hereto and their respective officers, agents and employees) and from and against any and all claims, demands or actions for such loss, injury or damage, and any costs or expenses in connection therewith, caused by or growing out of the taking of such borings or the occupying of the property of the Railway Company, whether caused in whole or in part by the fault, failure or negligence of Railway Company, its officers, agents, or employees or otherwise.

4 (a) Insurance

The ..... shall insure the contractual liability ..... has assumed under the provisions of Sec. 4. Indemnity. The coverage shall be not less than $..... for injury to or death of one person and $..... for injury to or death of more than one person in any one accident, and for injury to or destruction of property the coverage shall be $..... each accident and $..... in the aggregate.

The ..... shall furnish the Chief Engineer of the Railway Company with a signed or certified copy of the policy endorsed to cover the contractual liability assumed under Sec. 4. Indemnity.

No work will be permitted on Railway Company's right-of-way until satisfactory evidence of insurance coverage has been furnished and approved by the Railway Company's Chief Engineer.

Report on Assignment 2

Form of Lease Covering the Use of Railway Tracks for Storage of Tank Cars Containing Liquefied Petroleum Gases, Anhydrous Ammonia and Other Flammable or Dangerous Materials

Collaborating with the Fire Prevention and Insurance Section, AAR

W. D. Kirkpatrick (chairman, subcommittee), G. H. Beasley, R. F. Correll, Manuel Garcia, C. L. Gatton, E. M. Hastings, Jr., L. W. Lindberg, E E. Phipps, W. R. Swatosh, J. W. Wallenius.

Given this assignment in June 1958 by special action of the Board Committee on Outline of Work at the urgent request of R. G. May, vice president, Operations and Maintenance Department, AAR, your committee submits the following form of agreement as information, and as a pattern, with the request that members of the Association give us the benefit of their suggestions and criticisms, looking toward adopting the material for publication in the Manual next year.

FORM OF LEASE COVERING THE USE OF RAILWAY TRACKS FOR STORAGE OF TANK CARS CONTAINING LIQUEFIED PETROLEUM GASES, ANHYDROUS AMMONIA AND OTHER FLAMMABLE OR DANGEROUS MATERIALS

THIS LEASE, made this ..... day of ..... 19 ...., by and between ....., a corporation organized and existing under the laws of the State of ....., hereinafter called the Railway Company and ...., hereinafter called the Lessee.

WITNESSETH:

That the Railway Company, in consideration of the rents to be paid and agreements to be performed by Lessee, hereby leases unto Lessee all those certain tracks and appurtenant lands hereinafter called "premises", situated in the ..... County of ..... State of ..... described as follows:

1. Description

.... in accordance with plan ....., dated, ... designated as ..... hereto attached and made a part hereof.

2. Purpose

The premises shall be used solely for storing tank cars owned or leased by Lessee containing .....

3. Service

Upon the terms and conditions of this agreement expressed, Lessee shall be served by Railway Company's locomotives and crews over the hereinbefore described premises.

4. Notice

Any written notice given by the Railway Company to Lessee shall be deemed to be properly served if the same be delivered to Lessee, or one of Lessee's agents, or if posted on the premises, or if mailed, postpaid, addressed to Lessee at Lessee's last known place of business.

5. Rent

Lessee shall pay to the Railway Company a rental of ..... per ..... payable ..... in advance, beginning ....., 19 ....

6. Refund

Rent paid in advance for a period extending beyond the termination of this lease shall be refunded to Lessee, unless such termination shall be on account of violation or non-fulfillment of any of the terms of this lease by the Lessee, or on account of abandonment of the premises by the Lessee, in which case the amount paid as rental shall be retained by the Railway Company.

7. Taxes and Charges

Lessee shall pay during the term of this lease all taxes, licenses and other charges which may be assessed or levied upon the premises, and upon the business of Lessee upon the premises, or against the Railway Company by reason of occupation or use of the premises.

8. Condition of Premises

Lessee shall at all times keep the premises in a safe, clean and sanitary condition, and shall not mutilate, damage, misuse, alter or permit waste thereon. The Railway Company reserves the right to inspect the premises.

9. Laws and Regulations

Lessee shall, with respect to any of Lessee's cars placed or stored on the premises which contain any flammable product or other products of a hazardous nature, comply with all applicable Federal, State or Municipal orders, regulations and ordinances, and with all orders, regulations and recommendations from time to time prescribed or published by any public authority having jurisdiction, or by the Railway Company, relating to the type of cars and the contents thereof, or of any safeguard safety device, or procedure to be used in storing said cars on premises.

10. Liability

Lessee covenants and agrees to indemnify, protect and save the Railway Company harmless from and against all loss of and damage to any property whatsoever (including property of the parties hereto and of all other persons whomsoever), and all loss and damage on account of injury to or death of any person whomsover (including employees and patrons of the parties hereto and all other persons whomsoever), and all claims and liability for such loss and damage and cost and expense thereof, caused by or growing out of the operations of this lease or the presence of said cars, or their contents, on the premises, whether caused by the fault, failure or negligence of the Railway Company, its agents, servants, employees or otherwise.

11. Insurance

Lessee, at its cost and expense, shall procure and during the continuance of this lease maintain in effect a policy of insurance acceptable to the Railway Company insuring Lessee's liability under this agreement in amounts for injury to or death of one person not less than $..... and not less than $..... any one accident, and for damage to property not less than $..... any one accident. The Railway Company shall be furnished with a certified copy of the policy which shall be endorsed to provide for 30 days written notice to the Railway Company prior to termination of the policy and before any changes are made therein. The furnishing of insurance shall not be deemed a limitation on the liability of Lessee as provided in this agreement but shall be additional security therefor.

12. Term

To have and to hold the same from ....., 19 ...., to ....., 19 ...., unless sooner terminated, as hereinafter provided.

13. Termination

Either party hereto may terminate this lease at any time, by giving to the other party ..... days written notice to this effect as herein provided. Acceptance of rent in advance by the Railway Company shall not act as a waiver of the right to terminate this lease.

14. Abandonment

The failure of Lessee to occupy or use the premises for the purpose herein mentioned for ..... days at any time shall be deemed an abandonment thereof. An abandonment of the premises by Lessee shall, at the option of the Railway Company, operate as an absolute and immediate termination of this lease without notice.

15. Forfeiture

Any breach of any covenant, stipulation or condition herein contained to be kept and performed by Lessee, shall be sufficient cause for the immediate termination of this lease.

16. Insolvency or Bankruptcy

If Lessee at any time during the continuance of this agreement should become insolvent or bankrupt, or if Lessee's affairs should be placed in the hands of a Receiver, this lease shall, at the option of the Railway Company, terminate.

17. Renewal

A lawful continuance of the tenancy beyond said term shall be deemed a renewal thereof for the further term of ..... to end at the expiration thereof, without further notice; and every further lawful continuance shall be deemed a further renewal for a like term, to end in like manner, and every renewal or holding over shall be subject to the provisions of this lease.

18. Assignment

This lease shall not be assigned or in any manner transferred, nor shall said premises or any part thereof sublet, used or occupied by any party other than the Lessee, nor for any purpose other than that specified herein, without written consent of the Railway Company.

19. Successors

Until terminated as hereinbefore provided, this lease shall inure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors, and assigns.

In Witness Whereof, the parties hereto have executed this lease in .....
....., as of the day and year first above written.

Witness: ....Company

By: .....

Witness: ....Lessee

By: .....

Report on Assignment 3

Form of Lease Covering Right to Strip Mine on Railway Miscellaneous Physical Property

D. F. Lyons (chairman, subcommittee), J. J. Baffa, G. H. Beasley, H. F. Brockett, R. F. Correll, G. K. Davis, E. M. Hastings, Jr., A. F. Hughes, F. M. Jones, W. D. Kirkpatrick, L. W. Lindberg, W. L. Mogle, J. L. Perrier, E. E. Phipps, D. H. Yazell, H. L. Zouck.

Progress is being made in the study of this assignment, and the committee hopes to have a tentative form of agreement to present as information next year.

Report on Assignment 4

Form of Agreement Covering Parallel Occupancy of Railway Right-of-Way Property by Electric Power Lines

K. A. Begemann (chairman, subcommittee), J. J. Baffa, H. F. Brockett, A. B. Costic, R. C. Heckel, E. M. Hastings, Jr., A. F. Hughes, F. M. Jones, W. J. Malone, W. L. Mogle, C. M. Sherman, K. J. Silvey, J. W. Wallenius, D. J. White, D. H. Yazell, H. L. Zouck.

Last year your committee presented as information a draft of agreement form covering parallel occupancy of railway right-of-way property by electric power lines (Proceedings, Vol. 59, 1958, pages 435 to 439, incl.) and invited suggestions and criticisms thereof.

Having received no criticisms, your committee recommends that this agreement be adopted and published in the Manual at the end of Part 3, Electrical Agreements, Chapter 20.

Report on Assignment 6

Form of Agreement for Construction and Maintenance of Highway–Railway Grade Separation Structures for Public Roads

J. L. Perrier (chairman, subcommittee), K. A. Begemann, H. F. Brockett, Manuel Garcia, C. L. Gatton, J. F. Halpin, E. M. Hastings, Jr., D. F. Lyons, W. J. Malone, G. W. Patterson, C. M. Sherman, K. J. Silvey, W. R. Swatosh, D. J. White, Clarence Young.

Your committee presents as information a tentative draft of form of agreement for construction and maintenance of highway–railway grade separation structures for public roads. It invites your comments and suggestions.

FORM OF AGREEMENT FOR CONSTRUCTION AND MAINTENANCE OF HIGHWAY–RAILWAY GRADE SEPARATION STRUCTURES FOR PUBLIC ROADS

THIS AGREEMENT, made this ..... day of ..... 19 ...., by and between the State Highway Commission of ..... hereinafter called the State, and the ..... Railway Company,

a corporation organized and existing under the laws of the State of ....., hereinafter called the Railway Company.

WITNESSETH:

WHEREAS, the State desires to improve a portion of the highway system known and described as Highway No. ....., located in Section ....., Township ....., Range ....., in the Town of ....., ... County, ... and

WHEREAS, the Railway Company is the owner of certain land, rights-of-way, tracks and facilities in the aforementioned district, and

WHEREAS, in connection with the improvement to said highway the State desires to cross (over) (under) the lands, tracks and other facilities of the Railway Company by means of a grade separation structure designated Highway Structure No. ..... hereinafter called Crossing Project, as shown on the general plan dated ....., ..., marked Exhibit "A" attached hereto and made a part hereof;

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Plans and Specifications

The State shall prepare detailed plans and specifications for the Crossing Project and shall submit all such plans and specifications insofar as they affect the safety, operation or interests of the Railway Company to the Chief Engineer of the Railway Company for approval. All plans, specifications or modifications thereof shall bear the written approval of the Chief Engineers of the parties to this agreement. The Railway Company will prepare the detailed plans, specifications and estimates for such changes in, additions or alterations to its facilities as may be required in connection with the Crossing Project. Award of contracts shall have the written approval of the Railway Company where such contracts affect the interests of the Railway Company.

2. Permit

The Railway Company agrees to permit the construction and maintenance of the grade separation and highway approaches, including the drainage thereof and other appurtenances thereto, (over) (under) its tracks and across its operating right-of-way, subject to all the covenants and agreements herein set forth. All other property or right-of-way required for the project shall be procured by the State at no expense to the Railway Company. The State shall give written notice to the Railway Company 30 days in advance of entering onto Railway Company property for purposes of constructing or maintaining the Crossing Project.

3. Work by the State

After approval of the plans and specifications by the Railway Company, the State shall contract for and cause to be performed in accordance therewith, all work in connection with the construction of the entire Crossing Project, excepting, however, work to be performed by the Railway Company as hereinafter set forth in Sec. 4. All work herein provided to be done by the State, or its contractor, on the right-of-way of the Railway Company, shall be done in a manner satisfactory to the Railway Company, and the State shall require its contractor to avoid delay or damage to the Railway Company's operations, property, or other facilities, or the operations, property or facilities of others occupying or using its property. Upon completion of the items of work as herein stated, the State shall require its contractor to remove from the Railway

Company's right-of-way his machinery, equipment, temporary buildings and surplus material, and to leave the right-of-way in a condition satisfactory to the Railway Company.

4. Work by the Railway Company

Upon ..... days written notice by the State to proceed with the work, the Railway Company will furnish the materials and equipment, and proceed with the work, both temporary and permanent, in connection with any adjustment of any Railway Company facilities which may be necessary in the course of construction or maintenance of the Crossing Project. The Railway Company shall have the right to perform all or any part of this work with its own forces or by contract, provided, however, that any contract which the Railway Company shall elect to enter into shall first have the written approval of the State.

5. Protection of Railway Traffic During Construction

(a) The State agrees that the safety and continuity of the operation of the traffic of the Railway Company shall be of first importance and shall be at all times protected and safeguarded. The State shall require its contractor to perform and arrange his work accordingly. Whenever, in the judgment of the Chief Engineer of the Railway Company or his authorized representatives, the work or its performance may affect or involve the safety of the Railway Company's facilities and operation of its railway, the method of doing such work shall first be submitted to the Chief Engineer of the Railway Company for his approval, without which it shall not be commenced or prosecuted. The approval of the Chief Engineer of the Railway Company, when given, shall not be considered as a release from responsibility or liability for any damage which the Railway Company may suffer, or for which it may be held liable, as a result of the acts of the contractor or their subcontractors or their employees.

(b) The State shall give written notice to the Chief Engineer of the Railway Company not less than ..... days in advance of the commencement of work on or over the Railway Company's right-of-way, in order that the Railway Company may make the necessary arrangements for the protection of the Railway Company's operations.

(c) When deemed necessary by the Railway Company, it may assign or employ an Inspector(s) or Engineer(s), who will be placed on the work during the time the State's contractor is performing the construction provided for herein. The State shall reimburse or cause the Railway Company to be reimbursed for the cost and expense of such Inspector(s) or Engineer(s).

(d) Whenever in the opinion of the Railway Company the construction may cause a hazard to the safe operations of the Railway, the Railway Company may place qualified employees at the site of the work to protect its operations. The providing of such employees and such other precautions as may be taken shall not relieve the State or its contractor or subcontractors from liability for the payment of damages caused by their operations, and for the purpose thereof such employees of the Railway Company shall be considered as employees of the contractor or subcontractor. The Railway Company shall be the sole judge of necessity, number and classification of employees required. The State shall arrange for the prompt reimbursement to the Railway Company as provided in Sec. 10 for all cost and expense of providing such employees.

6. Federal Participation (If Applicable)

It is mutually understood that under various Federal Aid Highway Acts, certain funds have been made available to the State for highway improvements, and the Crossing Project herein contemplated may be financed in part by the use of such funds. It is therefore agreed that all plans, specifications, estimates, awards of contract, acceptance of work and general procedure shall be subject to all Federal laws, rules and regulations applicable to the portion of the work to be performed under this agreement as a Federal project.

7. Mutual Consultation and Cooperation

It is understood and agreed between the Railway Company and the State that each shall conduct its work, or cause its work to be conducted, in such a manner as not to unduly impede the work of the other, and that they shall confer with each other with respect to the various parts of the work before and during the progress of same for the purpose of preventing interference or delays and securing full cooperation in the expeditious handling of the Crossing Project. Each shall, upon notice from the other of any default or failure of any party, firm or corporation performing work under contract with respect to any part of this Crossing Project, promptly proceed to secure full compliance with the approved plans and specifications.

It is expressly understood and agreed that the Crossing Project includes no work for which the Railway Company is to be billed by the State. It is further understood and agreed that no contractor for the State shall bill the Railway Company for any work which he may perform, unless the Chief Engineer of the Railway Company shall have given a written request to the contractor for such work to be performed at the expense of the Railway Company.

8. Future Attachments to Crossing Structure

The Railway Company shall have the right, at its own cost and expense, but subsequent to the initial attachments which are a part of this project, to attach to the crossing structure from time to time, and to thereafter maintain, alter, change, repair and renew, without charge therefor by the State, such equipment, signal, communications, power or transmission line, cables, conduits and pipes, or other facilities as may be requisite or useful in the operation of the Railway Company, provided, however, that the manner and method of attachment shall first be submitted to and have the approval of the Chief Engineer of the State and shall be of such character as not to interfere with the safety, operation or maintenance of the highway crossing structure.

9. Future Maintenance of Facilities

The Railway Company agrees that, after completion of the said crossing structure and acceptance of the same by the State, the Railway Company will, at its own expense, maintain, repair and renew all of its railway facilities, including, but not restricted to, signals, communications and power lines which may be affected or relocated by reason of the crossing structure. The State agrees to own, and at its own expense to maintain, repair and renew the entire bridge structure, its approaches, substructure and superstructure, appurtenances, and the sidewalk and the roadway then or after located on the crossing structure, approaches and the drainage system, all of which shall be and remain the property of the State; the State further agrees to keep said highway crossing structure in a suitable, safe and secure condition, so as not to impede, jeopardize or interfere with the full, free and safe use, operation and enjoyment by

the Railway Company of its railroad appurtenances and property, as the same may now or hereafter exist. In any event, the State shall, if requested by the Railway Company, make such repairs and renewals as may be necessary to keep the crossing structure in such suitable, safe and secure condition. If the State shall fail or neglects to do so, the Railway Company shall have the right, on reasonable notice, to do so, and the State shall promptly reimburse the Railway Company for its cost and expense therefor. Nothing in this agreement shall release either party from claims for damage caused to the property of the other party.

10. Payment for Work

It is mutually agreed that the Railway Company will not bear any part of the expense of the Crossing Project and the State shall reimburse the Railway Company for all cost incurred by the Railway Company, connected with the Crossing Project, including, but not limited to, the following:

(a) Costs of all surveys, including preliminary, preparation and checking of plans, estimates and specifications, expenses of all inspection during the progress of the work, including wages, salaries and expenses paid the Railway Company employees (exclusive of general supervisory personnel) directly engaged in surveys, plan preparation and progress inspection, plus ..... percent of such wages and salaries as reimbursement for the costs of supervision and administration.

(b) All costs arising under any contract for any portion of the work, provided said contract has been approved by the Chief Engineer of the State, plus ..... percent for accounting and supervision.

(c) All costs for labor furnished directly by the Railway Company, including all wages, salaries and expenses paid by the Railway Company to its employees (exclusive of general supervisory personnel) engaged in the work, plus ..... percent of such labor costs and reimbursement for the costs of supervision and administration.

(d) All costs for materials furnished by the Railway Company, plus stores expense at the rate of ..... percent of the value of materials furnished by the Railway Company's Stores Department, and purchase expense at the rate of ..... percent on the cost of materials furnished through the Railway Company's Purchasing Agent as reimbursement for the costs of handling, supervision and administration.

(e) All costs of Workmen's Compensation or Employer's Liability insurance and Federal Employer's Liability, Fire insurance, Public Liability and Property Damage, Railroad Protective Liability and Property Damage insurance.

(f) All applicable taxes levied and paid on any materials purchased for the work.

(g) Rental of tools, equipment and machinery (including locomotives and work trains), rolling stock and roadway machines furnished by the Railway Company at established rental rates.

(h) Cost of bond premiums and cost of fees for all permits and licenses.

(i) Vacation allowances and all taxes, Federal and State, based on compensation by the Railway Company to employees engaged in the work.

(j) Cost of transportation for materials and equipment over the Railway Company's lines as well as over other railway lines, at current commercial rates.

(k) Such other items of expense as may be agreed upon by the Chief Engineer of the Railway Company and the Chief Engineer of the State.

The State shall pay the Railway Company for its costs and expenses incurred in the performance of the obligations of the Railway Company under this agreement in the following manner:

The Railway Company shall render to the State each month ..... copies of statement of the costs and expenses incurred in the preceding calendar month based on an estimated percentage of the work completed. Within ..... days after receipt of such statement the State shall pay to the Railway Company ..... percent of the total amount of said statement. Upon completion of all work to be performed by the Railway Company under this agreement, the Railway Company shall render ..... copies of a final bill to the State. Within ..... months after receipt of said final bill by the State and during which time the State shall have had an opportunity to audit said final bill the State shall pay the balance to the Railway Company.

If requested by the State, the Railway Company will furnish evidence and permit examination during regular working hours of its records pertaining to the Crossing Project from which the invoices have been prepared.

11. Temporary Crossing

If the State, or its contractor, should require a temporary crossing over the tracks of the Railway Company, they shall secure a license for same from the Railway Company.

12. Insurance

In addition to the insurance that the State may require its contractor to carry, the Railway Company shall take out insurance in amount of $..... which will protect and save harmless the Railway Company from and against (1) all loss of, and damage to, any property whatsoever, including property of the parties hereto, and of all other persons whomsoever, and the loss of, or interference with, any use of service thereof; (2) all loss and damage on account of injury to, or death of, any person whomsoever, including employees and patrons of the parties hereto and all other persons whomsoever; and (3) all claims and liability for such loss and damage and cost and expense thereof caused by, growing out of, or in any way related to, or connected with the construction and maintenance of the Crossing Project covered by this agreement, whether or not caused by the negligence of the Railway Company. The State shall reimburse the Railway Company for the costs of such policies.

13. Indemnity

The State shall indemnify and save harmless the Railway Company from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description made, brought or recovered against the Railway Company by reason of any act or omission of the State, its agents or employees in execution of the work or in guarding the same.

14. Failure of Performance

If at any time the work which is herein agreed to be done shall cease and not resumed within ..... days without fault of the Railway Company, the Railway Company may take whatever action is necessary to restore its properties and facilities to such satisfactory permanent operating condition as it may consider necessary, and the State hereby agrees to reimburse the Railway Company for any and all cost incurred by the Railway Company in connection therewith.

15. Duration and Succession

The terms and conditions of this agreement shall inure to the benefit of and be binding upon the parties hereto, their respective successors and assigns during the use and operation of the grade separation structure.

In Witness Whereof, the parties hereto have caused this agreement to be duly executed in ..... as of the day and year first above written.

.....Railway Company

Witness: ..... By .....

(Title)

The State of .....

Witness: ..... By .....

Report of Committee 6—Buildings

S. G. Urban, *Chairman,*
D. W. Converse, *Secretary,*
J. L. Agee
C. M. Angel
W. F. Armstrong
S. M. Bielski
G. J. Bleul
C. E. Booth
H. M. Booth
J. R. Bowman
R. R. Cahal
H. M. Church (E)
C. E. Close
J. S. Cooper
F. D. Day
C. E. Defendorf
A. G. Dorland (E)
L. A. Durham, Jr.
V. E. Elshoff
T. J. Engle
R. L. Fletcher
I. G. Forbes
C. S. Graves
J. W. Gwyn
W. G. Harding
A. T. Hawk (E)
Wm. Hayduk
J. W. Hayes
J. F. Hendrickson
K. E. Hornung
B. J. Johnson, Jr.
T. M. Kelly
Earl Kimmel
S. E. Kvenberg
R. E. Lilliston
G. H. McMillan
A. A. Melius
I. A. Moore
J. D. Moore, Jr.
G. A. Morison
D. J. Murray
L. S. Newman
W. C. Oest
D. E. Perrine*
T. V. Pyle
C. L. Robinson
J. T. Rowan
A. B. Ryan
J. B. Schaub
J. T. Schoezner
H. T. Seal
Loren Shedd
E. R. Shultz
R. C. Turnbell
J. W. Wagner
J. W. Westwood
O. G. Wilbur
N. H. Williams
T. S. Williams

Committee

(E) Member Emeritus.
* Chairman up to the time of his death on September 21, 1958

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Specifications for railway buildings.

   Progress report, with specifications recommended for adoption ..... page 316

3. Prefabricated metal buildings for railway use.

   No report.

4. Wind loading for railway building structures.

   No report.

5. Expansion, contraction and control joints in concrete and masonry block buildings.

   No report.

6. Buildings and structures for hump classification yards with retarders, collaborating with Committee 14.

   Final report, submitted as information ..... page 317

7. New structural systems for railway buildings.

   No report.

8. Infra-red ray heating, collaborating with Electrical Section, AAR.

Progress report, submitted as information ..... page 324

THE COMMITTEE ON BUILDINGS,
S. G. URBAN, *Chairman.*

AREA Bulletin 546, November 1958.

MEMOIR

Dwight Elvin Perrine

It is with deep regret and sorrow that we, the members of Committee 6—Buildings, record the passing of our esteemed chairman, Dwight E. Perrine, assistant chief engineer, Chicago & Western Indiana Railroad; Belt Railway of Chicago.

Mr. Perrine was born in Cedar Point, Kans., on March 16, 1901, and passed away after six months' illness on September 21, 1958.

His higher education was received at St. Joseph, Mo., Junior College and the Georgia Institute of Technology.

In the summer of 1917 he entered railroad service as a chainman with the Atchison, Topeka & Sante Fe Railway at Topeka, Kans. After serving in the U. S. Naval Reserve, he progressed through many railroad and contracting positions, finally joining the C&WI and the Belt Railway as assistant engineer in 1948. Promotions followed rapidly to his position as assistant chief engineer, in which capacity he served until the time of his death.

Mr. Perrine joined the AREA in 1948 and became a member of Committee 6 in 1951, vice chairman in 1953 and chairman in March 1956. He was also second vice president of the Maintenance of Way Club of Chicago, a member of the American Railway Bridge and Building Association, the Roadmasters' and Maintenance of Way Association of America, the Western Society of Engineers, the Chicago Engineers Club, and was a devoted member and secretary of the South Lawn Community Methodist Church.

Mr. Perrine is survived by his wife, Marie C. Perrine, and one married daughter, Mrs. Marilynne Ann Lorenzo.

He will be remembered by his colleagues for his willingness to give freely and wholeheartedly of his time and efforts to further committee goals, and for his friendly relationship with everyone who was privileged to know him.

Report on Assignment 2

Specifications for Railway Buildings

H. T. Seal (chairman, subcommittee), J. R. Bowman, R. R. Cahal, C. E. Close, F. D. Day, C. E. Defendorf, T. J. Engle, Wm. Hayduk, B. J. Johnson, Jr., S. E. Kvenberg, A. A. Melius, I. A. Moore, L. S. Newman, T. V. Pyle, C. L. Robinson, J. T. Rowan, J. T. Schoener, T. S. Williams.

Your committee submits the following specifications for application of asphalt shingles with the recommendation that they be adopted and published in the Manual at the end of Part 10—Roofing and Siding.

SPECIFICATIONS FOR APPLICATION OF ASPHALT SHINGLES

1. General

The contractor shall furnish all labor, superintendence, materials, tools, equipment, and transportation, except as otherwise provided, needed to apply completely the asphalt roofing shingles as specified or shown on the drawings.

2. Materials

All roofs having a pitch of 4 in or more to the foot shall be covered with asphalt shingles weighing not less than ..... lb per square, color as selected, as manufactured by ...., or approved equal.

3. Application

When used over wood sheathing, one layer of standard asphalt-saturated rag felt of not less than 15 lb weight, lapped at least 2 in at all joints, shall be applied before the shingles are laid.

When the application is made over old wood shingles, all decayed and missing shingles shall be replaced and all loose and curled shingles securely nailed down to make the surface as smooth as possible. It may be necessary to smooth out the old roof deck by nailing on beveled wood strips with the thick edges against the butts of the wood shingles.

All asphalt shingles and flashing shall be applied in strict accordance with the manufacturer's directions.

4. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Part 1, this Chapter, shall be considered to apply with equal force to this specification.

Report on Assignment 6

Buildings and Structures for Hump Classification Yards with Retarders

Collaborating with Committee 14

A. B. Ryan (chairman, subcommittee), J. L. Agee, J. S. Cooper, V. E. Elshoff, Wm. Hayduk, J. W. Hayes, J. F. Hendrickson, B. J. Johnson, Jr., Earl Kimmel, A. A. Melius, J. D. Moore, Jr., L. S. Newman, W. C. Oest, C. L. Robinson, J. T. Rowan, J. B. Schaub, H. T. Seal, J. W. Westwood, T. S. Williams.

This is a final report, presented as information.

Every retarder yard has its own particular requirements which are impossible to cover in a recommended-practice report. However, all yards have certain essential requirements for buildings. For instance, every retarder yard must have a retarder tower, one or two yard offices and checker buildings. These are the absolute essentials.

Confining its remarks to retarder yards wtih 50 to 60 classification tracks, your committee presents below, in detail, the ideal requirements for the four most essential

types of buildings: retarder tower, main yard office at hump, yard office between classification and departure yards (referred to hereinafter as bowl yard office), and car inspector booth ahead of hump. It also presents brief information on checker buildings and tool and storage buildings.

RETARDER TOWERS

Depending on the operation of the yard, one or two retarder towers located adjacent to the retarders at the hump are necessary—one if the humpmaster controls the switching from the hump, two if the retarder operators handle switching as well as the retarders. However, if fully automatic retarders and switching are provided, then only one tower and one operator are necessary.

The most economical height for a retarder tower has been found to be three stories. However, this building should be so located and be of such height as to enable the operator on the third floor to have a clear view of the cars and retarders under his control. Experience has found that the operator's eye level should be from 25 to 30 ft above the top of rail.

Occupancy

The first and intermediate floors of the tower may house electric power panels, battery room, signal maintenance work shop, retarder and switching controls, communication equipment utility room, and possibly signal supervisor's or assistant supervisor's office.

If the retarders are operated by compressed air instead of electricity, space for compressors and possibly a standby generator should be provided on the first floor of the tower; however, these facilities are usually housed in a separate building. A separate building has been found to be more desirable, because ventilation of a compressor room is important to dispel the heat generated by this equipment. Also, these compressors and standby generators cause a noise and vibration problem which is objectionable to the retarder operators.

Space Requirements

1. *Electric Power Panels:* Electric panel space should be provided accessible to an outside door. The wall space for these panels should be a minimum of 6 ft in length, with ample floor space adjacent to panels for accessibility.

2. *Signal Maintenance Work Shop:* Considerable inside space is required, probably varying from 600 to 800 sq ft, with outside covered platform area for maintenance of heavy equipment. This outside area should also have a monorail hoist for loading and unloading trucks.

3. *Retarder and Switching Automatic Controls:* This requires approximately 700 sq ft of floor space. An elongated shape is better suited for this space, because of the long relay racks required in 2 or 3 rows with ample space in front and back of the relays for the performance of maintenance and repair work. A desirable width for this space should be a multiple of 5 ft (15 or 20 ft, depending on the number of rows of relays required) and a length suitable for the lengths of the relay racks (40 to 60 ft).

4. *Battery Room:* A space of approximately 150 sq ft is required for battery storage and recharging. This space could be incorporated with the signal maintenance work shop. This area should be adequately ventilated for the removal of hydrogen gas. If electrically operated retarders are used, a larger battery room will be required.

5. *Private Office:* This office space for the signal department supervisory force, approximately 200 sq ft, can usually be located on the intermediate floor or floors.

6. *Utility Room:* Space is required to house a boiler, air conditioning equipment, etc. A fire wall should be installed between this area and the relay room, insuring protection for the expensive electrical equipment located in the relay room.

7. The tower room dimensions need not be more than 16 by 16 ft. A toilet with one water closet and one lavatory should be located in adjacent room.

Materials

The tower building should be constructed of approved non-combustible materials. The exterior walls and wall panels should have a fire-resistance rating of not less than 4 hr. All bearing walls should be constructed of masonry or reinforced concrete. All structural steel used should be protected to provide a fire-resistance rating of not less than 4 hr. All floor and roof construction should have a fire-resistance rating of not less than 3 hr. Walls, ceilings and floors of automatic control or relay rooms must be finished as required to eliminate dusting.

Fire Protection

Adequate fire protection should be provided for this building, including the use of hose racks located on the first and third floors.

Recommended Type of Construction

It has been found that windows are not desirable in the exterior walls of the relay room located on the first floor, because this area is for electrical equipment only and infiltration of dust is a critical problem.

Access to the second and third floors is more economically obtained by the use of an outside open-grating stair wrapped around the tower portion of the building. However, in climates where icing and snow is a problem the installation of an elevator is desirable. This elevator should have a one- or two-passenger capacity. Or, consideration might be given to a step-on-type vertical endless belt, electrically or manually operated.

The open grating should extend around the third floor (at approximately floor level) to solve the problem of cleaning the large plate glass window of the tower.

Assuming the tower faces the track, the plate glass window should wrap around on each side of the building, extending back from the front corners of the building 4 to 6 ft. The glass of this window should be ¼-in plate, heat-absorbing glass. The glass should be approximately 2 ft off the floor and 4 ft high, installed in self-supporting sash. It is also recommended that this glass be installed at an angle, sloping in from top to bottom; this tends to eliminate glare at night. In the northern part of the United States and in Canada it is advisable to use double-glazed finestration to reduce heat loss. All glass should be tinted.

The roof overhang of the tower is important. It not only protects the observer's eyes but improves visibility. Experience has found that an overhang of 4 ft is the minimum and that 6 ft is preferable. When the yard is laid out north-and-south, requiring the tower to face either east or west, then this problem of sun in the observer's eyes cannot be entirely overcome by roof overhang, making the use of glare-reducing, heat-absorbing plate glass absolutely essential.

Mechanical Facilities

The relay room and operator's room in the tower should have year-around air conditioning; the other areas in this building may or may not be air conditioned. Air conditioning is important in the relay room because of the desirability of maintaining

a constant temperature as well as controlling dust and dirt. If air conditioning on the second or intermediate floors is required, then a central air-conditioning system is the most logical and economical choice. However, if these intermediate floors are not to be air conditioned, then a separate and independent unit located in the tower is desirable. The first floor, including the relay room, can then be conditioned by one package air-conditioning unit located in the utility room of the first floor.

Wiring for lights, signals and retarders is one of the most important facilities in this building, and careful consideration must be given to the chase ways for the cables entering the building below grade as well as the openings in the intermediate floors.

Care should be taken in locating and choosing lights for the tower room. Too much light in this area will be a hinderance to outside vision at night, and promiscuous lighting will create unnecessary glare and reflection. Therefore, small carefully directed lights on the operator's machines are recommended. Or, still more desirable is to provide adjustable indirect lights that could be controlled to provide the same intensity of light inside as exists outside. Such adjustable lighting would permit clerical work in the tower when humping is not in progress.

MAIN YARD OFFICE AT HUMP

This building is the heart of the entire yard and is located at the crest of the hump. It may be a one- or two-story building, with a three-, four- or five-story tower for the yardmaster. It is difficult to establish standards for this building because of the variation of the operational requirements.

Occupancy

The following requirements are subject to operational revisions and additions:

1. Assembly or meeting room (optional).
2. Wash and locker room.
3. Space for tube system compressor.
4. Space for communication facilities.
   (a) Intercommunication equipment room, including radio.
   (b) Telephone equipment (optional).
   (c) Communication cable entrance room.
   (d) Communication maintenance shop (optional).
5. Terminal superintendent's office (optional).
6. Terminal trainmaster's office (optional).
7. Telegraph office.
8. Conductor's room (optional).
9. General office space—alloted as follows:
   (a) Crew clerks.
   (b) Crew caller.
   (c) Crew dispatcher.
   (d) Space adjacent to hump and scales for scale clerk and possibly the humpmaster.
   (e) Car taggers, car checkers, record clerks, list clerks, stenographers, etc.
   (f) Space for pneumatic tube terminals.
10. Yardmaster's tower room.
11. Utility room.

Space Requirements

If rock is not encountered, a full-size basement is usually found to be most economical. This is true especially when the scale pit is adjacent to the building, allowing access to the scale pit from the basement through a tunnel. The basement floor space can be utilized for an assembly room, utility or boiler room, wash and locker room, tube system compressor room and general storage room for records.

1. *Assembly or Meeting Room:* This space is for rules examinations and general assemblies. A capacity of 75 to 100 seats is usually sufficient. It is desirable to provide a projector and screen in this room.

2. *Wash and Locker Room* should have a locker capacity sufficient for the number of men required, and shower and toilet facilities to meet the local code requirements. It has also become an accepted practice to separate the shower and toilet facilities from the locker space with partitioning.

3. *Space for the Tube System Compressor* should be so located in the basement as to be under tube cabinets on the first floor. Space requirements will vary according to the number and length of tube lines in the yard. There is considerable noise generated in this area and should be considered in the design.

4. *Space for Communication Facilities:* These facilities can be located on one of the intermediate floors of the tower. However, heavy equipment storage should be provided in the basement.

(a) Intercom and radio room located directly under yardmaster's tower room.

(b) Commercial telephone or railroad-owned dial telephone equipment directly under intercom if four-story tower is provided.

(c) Communication cable entrance and distribution room located directly under tower in basement.

5. *Terminal Superintendent's Office* may or may not be required. If this space is required it is best located with 6. *Terminal Trainmaster's Office* on the second floor of the building. The second floor can be of such a size (full size if required) to accommodate these two officers with their clerical forces.

7. *Telegraph Office:* The floor area required for this space should be from 300 to 700 sq ft, depending upon the number of operators necessary for the operation of the yard. Noise resulting from the teletype machines is a factor in the design and location of this area.

8. *Conductor's Room:* It is desirable to locate this space adjacent to the telegraph office. However, some railroads have no provisions for conductors other than wash and locker facilities.

9. *General Office Space* requirements will vary with every yard, and it is impossible to set down specific requirements. However, experience has shown that a general office space of from 1500 to 2500 sq ft will suffice for most operations. Off this general office space a bay window should be provided for the scale operator. The bay is necessary for adequate vision up and down the scale track. This bay should project approximately 5 ft and have a width of approximately 10 ft. Some railroads have found it convenient to locate the humpmaster in a bay similar to the space occupied by the scale operator. Floodlights should be located above these bay windows for the illumination of car numbers. In some yards where the receiving lead track is convenient, one of the car checkers can work from a window of this building.

10. *Yardmaster's Tower Room:* A tower 20 ft square usually provides ample space for the yardmaster. A private toilet plus a small storage space should be incorporated

in this room. The yardmaster's view is the most important requisite for this tower room and should be kept in mind in the design. It is, therefore, recommended by some railroads that the toilet facilities for the yardmaster be located on the floor below, thereby, providing 180 deg vision in the tower room.

Materials

The construction of this building should conform to the general requirements for office buildings. The use of non-combustible materials is, of course, desirable.

A suspended acoustical ceiling is recommended over the first floor for sound control and the provision of space for the tube system and other mechanical facilities. Acoustical ceiling is also recommended for the yardmaster's tower room. It is also desirable to soundproof the walls around the telegraph room.

The plate glass windows for the scale operator and yardmaster should have approximately the same dimensions and characteristics as those given heretofore for the retarder tower. Also the overhang for the yardmaster's tower should have appoximately the same dimensions as suggested for the retarder tower.

Mechanical Facilities

Year-around air conditioning is recommended for all areas in this building except the wash and locker rooms, toilet rooms, record and storage areas and mechanical equipment rooms. A centralized heating and cooling plant is recommended, using separate heating and cooling units with a common air distribution system. Air distribution should be handled through a system of ductwork for both supply and return air. As in the case of the retarder tower, if the intermediate floors in the tower are not to be air conditioned, it is advisable to use a separate and independent air-conditioning unit in the yardmaster's tower room.

Men's and women's toilet rooms meeting the necessary code requirements should be located conveniently on the first and second floors.

Wiring and lighting should follow the usual accepted practices for offices with the exception of the yardmaster's tower room. This area should receive the same careful consideration in regard to lighting as suggested for the retarder tower.

Lighting—Recommended Levels

General office	50 ft-candles
Telegraph room	50 ft-candles
Private offices	30–40 ft-candles
Other rooms	20 ft-candles
Tower room	5–40 ft-candles (variable)

BOWL YARD OFFICE

This building is located between the classification tracks and the departure yard and is used principally by the yardmaster who handles the make-up of trains in the departure yard. It should have a tower room similar to the towers recommended for the retarder tower and yard office.

Occupancy

The first floor of this building should provide the following facilities:

1. Wash and locker room for switching crews.
2. Office space.
3. Utility room.

It is debatable whether the yardmaster's tower should be two or three stories high. If it has three floors, the second floor can be utilized by the telephone intercom, radio and signal departments.

Space Requirements

1. *Wash and Locker Room Facilities* should be incorporated into the first floor of this building with capacities to accommodate the required number of lockers. The toilet and shower facilities should meet the necessary code requirements for the required number of lockers. As suggested for the other buildings in this report, the wash and toilet room should be separated by a partition from the locker room.

The requirements for wash and locker facilities in this area between the classification and departure yards vary widely with each yard operation and must be determined according to the wishes of the mechanical department and transportation department.

2. *The General Office Space* in this building will vary considerably in space requirements, depending largely on whether an interlocking control machine is located in this space. This floor space will vary from 300 to 600 sq ft. In this area it is desirable to have a glass bay for the switching foreman similar to the bay in the main yard office for the scale operator.

3. *Utility Room* of 100 to 150 sq ft is usually adequate.

4. *Requirements for Yardmaster's Tower Room* located on either the second or third floor are similar to the yardmaster's tower in the main yard office.

Materials

See recommendations for Main Yard Office at Hump.

Mechanical Facilities

See recommendations for Main Yard Office at Hump.

Pneumatic tube lines and terminals are usually required in this building; therefore, provision for these facilities should be considered.

CHECKER BUILDINGS

There may be two, three or four of these small one-room buildings required. Usually there is one at the entrance of the receiving and departure yards or one at each end of these sections. They should have ample glass area for good vision in three directions. Usually only one man occupies these buildings, and a space of 100 to 150 sq ft is ample. If toilet facilities are not accessible, a small toilet should be considered in the design. Floodlighting the sides of cars from the roofs of these buildings should also be included in the design.

CAR INSPECTION BOOTH

Car inspection pits just ahead of the hump for the inspection of cars as they enter the yard might be located either between the rails or on each side of track. The floor area of these pits should be 50 to 100 sq ft. Side pits have been found to be most desirable. These pits should be depressed on each side of the track so that the car inspector, when seated, can view the under-frames and rigging of the cars with his eye-level just above (about 6 in) the top of rail. These pits should be of concrete construction with clear, shatterproof glass projecting approximately 2 ft above grade. Adequate floodlighting should be provided on top of the pits for the illumination of the undersides of cars.

TOOL AND STORAGE BUILDINGS

It is also desirable to provide small unheated tool and storage buildings at strategic locations in the yard to eliminate lost time and motion in transporting tools, materials, etc.

CONCLUSION

The above described buildings are the essential ones for a classification hump yard. The desirability of other facilities is realized, such as car icing, car repair, diesel and freight facilities, and for other miscellaneous and subordinate operations which consolidate and expedite freight traffic. This committee feels that the incorporation of these miscellaneous facilities into this report would be reiteration of studies made by Committee 14—Yards and Terminals.

Report on Assignment 8

Infra-Red Ray Heating

Collaborating with Electrical Section, AAR

J. W. Gwyn (chairman, subcommittee), S. M. Bielski, C. E. Booth, J. R. Bowman, D. W. Converse, L. A. Durham, C. S. Graves, J. W. Hayes, T. M. Kelly, R. E. Lilliston, G. A. Morison, O. G. Wilbur.

This progress report, presented as information, contains a brief explanation of the principles involved in infra-red ray heating and describes several installations where this heating is now used, such as in railroad car shops, passenger stations and similar buildings with high bays. Fuel consumption and operation costs, so far as presently available, are given for both gas and electric heaters.

The vital importance of heat from the sun is, of course, unquestioned, but the fact that all such heat is obtained by infra-red-ray transmission may not be thoroughly understood by all. These rays are generated by burning gases in the sun and are transmitted at the speed of light without heating the atmosphere through which they pass. But when they strike an object they are either reflected, absorbed or allowed to pass through the object. The portion of the rays which is absorbed are converted to heat which warms the surrounding atmosphere by secondary convection.

Entirely similar infra-red rays can be generated by heating a surface to the degree necessary to emit such rays. This heating can be accomplished either by gas or electricity. Infra-red radiation increases as the fourth power of the absolute temperature. For example, a surface having a temperature of 1600 deg F (2060 deg absolute) emits 96 times as much radiation to an equal-area surface at 200 deg F (660 deg absolute).

A type of heater using infra-red rays was patented in Germany and mass produced in 1952. It has been successfully used in cathedrals, exhibition halls, arcades, patios, outdoor cafes and factories. A manufacturer in the United States was soon licensed to make and distribute this brand of heater. The gas for these heaters may be either manufactured, propane or natural; however, except for very limited areas and occasional use, the cost for the first two mentioned would be excessive. The cost for natural gas is in many cases, low enough to permit its economical use as a fuel for infra-red heaters and it is becoming more widely available as pipelines are extended over the continent.

TABLE I

INFRA-RED RAY HEATER INSTALLATIONS

	Location	Occupancy	Size	Building Constr.	Roof	Fuel	Heaters			BTU Input	Floor Area	Thermostats		Ventilator	Installation		Operation	
							Heads	Shades				No.	Grouping		Date	Cost	Cost	Perform
1	Milwaukee Wis.	Crane Factory	80' x 400' x 47'	Transite	Steel	N. Gas	360	30	Elephant	4,320,000	32,000 sq. ft.	6	3 at 4 Shade 3 at 6 Shade	12 on G_L	10-1-57	$24,422	4 mo. $6,371	Good
2	Milwaukee Wis.	Welding	60' x 125' x 36'	Sheet Metal	Steel	N. Gas	21	7	Reflector	252,000	7,500 sq. ft.		1 at 1 Shade 1 at 2 Shade 1 at 4 Shade	8 on G_L (12 in. Gravity)	9-1-57			Good
3	Milwaukee Wis.	Fabri-cating	280' x 732' Various Heights	Transite	Steel	N. Gas	252 216	21 24	Elephant Reflector	3,024,000 2,592,000	48,000 sq. ft. Heated Note 2				1-1-57	$40,000	17.8 ¢ per sq. ft. per year	Good
4	Cleveland Ohio	Fabri-cating	100' x 380' x 39'	Stainless Steel	Precast Conc.	N. Gas		22 55	Elephant Reflector	4,320,000	38,000 sq. ft.				9-1-57	$38,105	3 mo. $2,139 Note 1	Good
5	Meadville Pa.	Erie Railroad Car Shops	75' x 250' x 41'	Alum. Siding	Steel	N. Gas	168	14	Elephant	672,000	13,125 sq. ft. (partial)	4	2 at 3 Shade 2 at 4 Shade	4 on G_L (18 in. Gravity)	11-1-56	$11,100	Note 3	
6	Butler Pa.	Interior Loading Platform	Restricted Information															
7	Restricted	Car Repair Shed	105' x 110' x 32' ±	Open Shed Partial Side	Steel	Elec.	108 Tubes	9 Rack	Reflector	691,064	Spot Heating		3 Stage Push Button Control	None	3-15-58			Good
8	Restricted	Car Repair Shed	105' x 110' x 32' ±	Open Shed Partial Side	Steel	Elec.	108 Tubes	9 Rack	Reflector	691,064	Spot Heating		3 Stage Push Button Control	None	3-15-58			Good
9	Harrison N. Y.	NYNY&H Railroad Pass Station	50' x 68' x 20' Irregular	Stone Veneer	Wood Ceiling	N. Gas	7&1	7	Reflector	452,500	2,500 sq. ft.	8	Individual	Each Heater Individually Vented	4-18-56	$2,746	22 mo. $2,374	Good

Note 1: Includes heating of two washrooms with duct furnace; also operation of a 50 gal. hot water tank.
Note 2: Area not separated from portion which has no heaters.
Note 3: Gas supply not separately metered to heaters.

TABLE 2

Estimated Operating Costs Per Heating Season

Type of Heat	Fuel	Labor	Other	Total
Coal	$ 43,500	$ 21,022	$ 7,252	$ 71,755
Oil No. 6	78,083	18,828	7,253	99,164
Oil No. 2	78,000		200	78,200
Natural Gas*				
Conventional System	107,000		200	107,200
Infra-Red	37,235		200	37,435

*Natural gas rate scheduled for reduction.

With the thought that this committee's study of the possibilities and economic advantages of infra-red ray heating for railroad buildings might in the future lead to a specification in the Manual, it was decided to inspect some existing installations. Nine different installations were visited and the results are shown in Table 1, which briefly outlines the salient facts in connection with the respective installations. Attention is called to the columns which show the cost of installation and operation; these figures, while not averaged over more than one heating season, are very significant in determining the applicability of this type heat to railroad buildings.

Installations 1 to 6, incl., as shown in Table 1, are representative of the type manufactured under the original German patent. Fig. 1 shows a typical installation of this type, including both overhead and wall-mounted units. Installation 5 in the Erie Railroad car shop at Meadville, Pa., is typical of this type, and photographs of it are shown in Fig. 2.

Electrically generated infra-red installations Nos. 7 and 8 are in practically identical car repair shops. Each shop has both ends and sides open; consequently the heaters serve as spot heaters. The heaters are arranged in two groups of two racks each on each of three tracks. The racks, which are 32 in high and 108 in long, are placed one on each side of the track at 7 ft 4 in from the center line of track, with the bottom of the rack being 8 ft 3 in above the top of rail. The racks are placed longitudinally to warm an area about 28 ft long. They are placed at a 45-deg angle to direct the rays downward on the desired area. The installation totals 12 racks, each with a consumption of 22.5 kw for a total of 270 kw, which, at the rate of 1 cent per kw-hr, means that their operation would cost $2.70 per hr. This cost is not considered excessive because the work performed can be done much more efficiently. The installation is so made that one or all of the heater racks may be activated and each rack may be operated at one-third, two-thirds or full capacity. This type of installation warrants consideration in areas such as that served by the Tennessee Valley Authority where the cost per kilowatt hour is one cent or under.

Another type of gas-fired, infra-red generator is of much different construction; however, only one such installation was inspected (see No. 9 in Table 1). Seven heaters of this type are included in this installation, along with another model distributed by the same company. This installation is in a passenger station and is considered satisfactory after two years of operation. Infra-red heaters of this type, according to its

(Text continued on page 330)

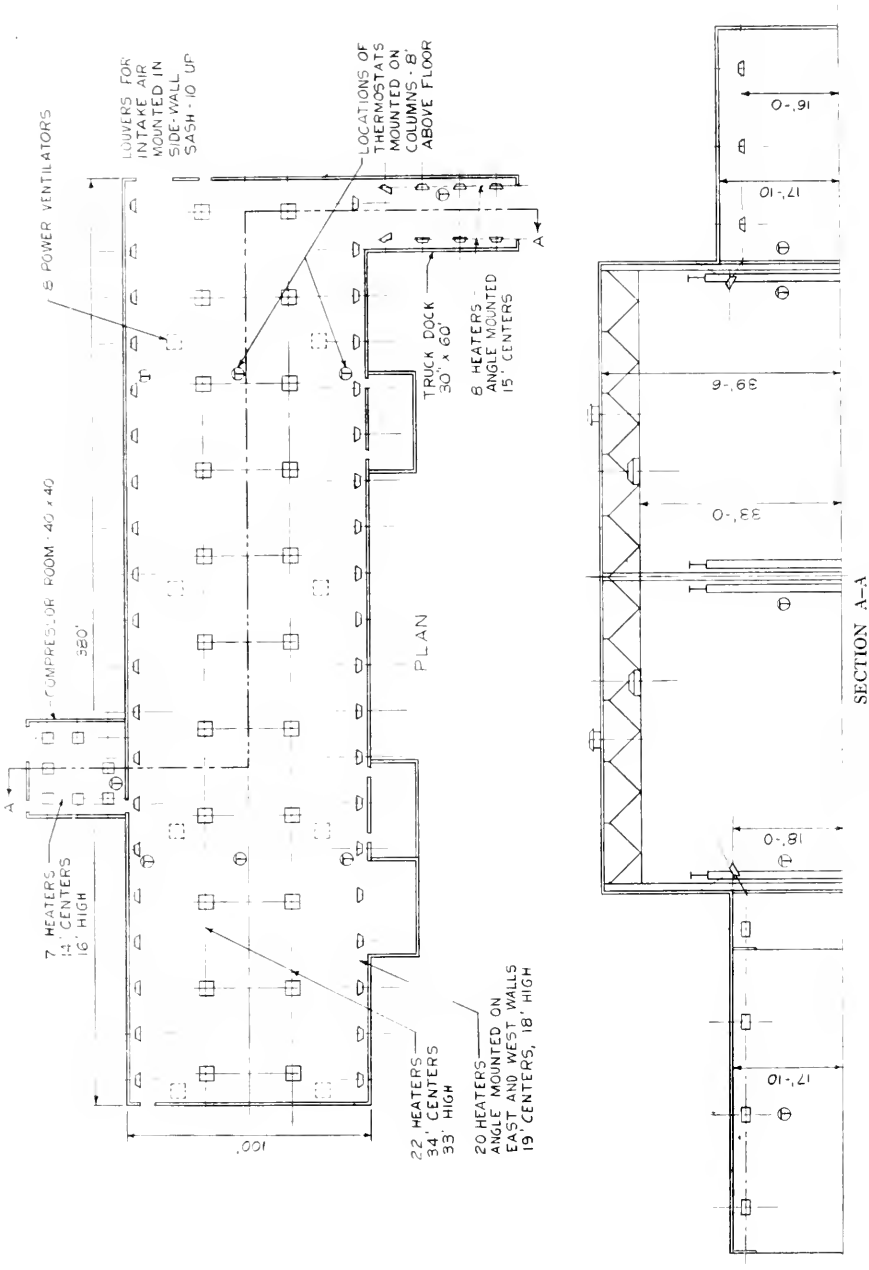

Fig. 1—Typical infra-red heating installation.

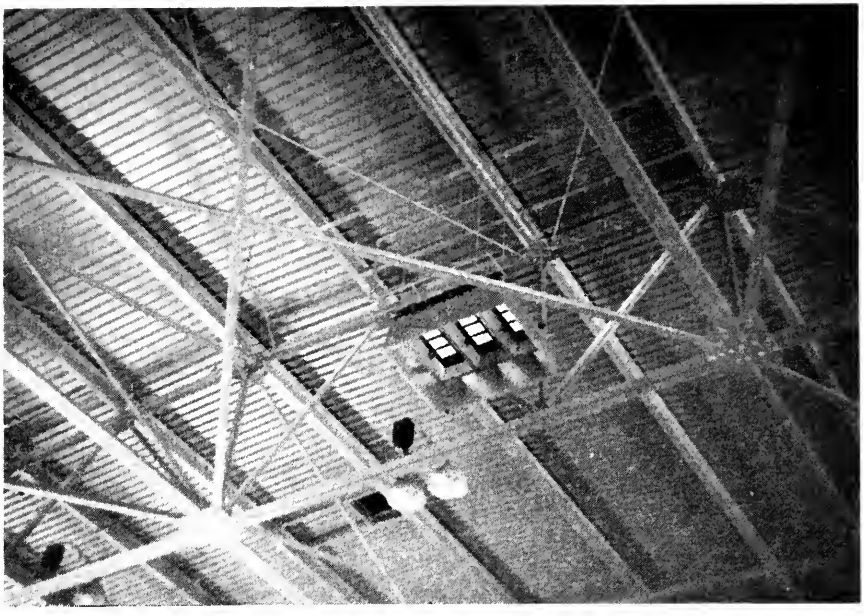

Fig. 2—Two views of heaters in Erie car shop, Meadville, Pa.

Fig. 3—Infra-red heaters in New Haven passenger station, Harrison, N. Y.

distributor, comprise more than 20,000 installations in the United States; consequently some features of this one installation, shown in Fig. 3, may be unique rather than typical.

There is no exact method of arriving at the required size and number of heaters used in spot heating or to heat open-sided buildings, but for closed buildings no unusual problem is encountered in arriving at the required number and size of heaters. The conventional method of determining the heat loss and required Btu's can be followed except that the air higher than 15 ft above the floor is assumed to be unheated; hence no heat loss is considered through the sides and ends of buildings above that level.

One major railroad has developed some estimated comparative costs of conventional and infra-red heating of the same building area. This information is shown in Table 2.

When considering use of gas-generated infra-red-ray heaters in areas subject to wind or draft, proper shielding should be provided to avoid possible blow-out of the gas flame. Also, if the building contains an automatic sprinkler system, it must be protected from freezing.

It is planned to inspect other installations which will include different types of gas-generated as well as electric infra-red-ray heaters.

Report of Committee 25—Waterways and Harbors

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Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress in study, but no report

2. Current policies, practices and developments dealing with navigation projects, collaborating with AAR Committee on Waterway Projects.
   No report.

3. Bibliography relating to benefits and costs of inland waterway projects involving navigation.
   Progress report, presented as information ..... page 332

4. Economic analysis of a completed waterway project.
   Progress in study, but no report.

6. Planning, construction and maintenance of rail–water transfer facilities.
   Progress report, presented as information ..... page 332

7. Relative merits and economics of construction materials used in waterfront facilities.
   Progress report, presented as information ..... page 335

The Committee on Waterways and Harbors,
F. B. Manning, *Chairman.*

AREA Bulletin 547, December 1958.

A

Report on Assignment 3

Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation

M. A. Michel (chairman, subcommittee), G. W. Becker, E. A. Beekley, C. M. Bowman, W. H. Eckenbrine, N. E. Ekrem, L. W. Haydon, R. B. Midkiff, J. G. Miller, W. J. O'Connell, J. G. Roney, R. S. Rowe, C. M. Segraves.

Your committee submits the following report of progress which presents five additional references not previously reported to the Association.

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Report on Assignment 6

Planning, Construction and Maintenance of Rail—Water Transfer Facilities

G. W. Mahn, Jr. (chairman, subcommittee), Arthur Anderson, G. W. Benson, R. L. Bostian, Jr., R. J. Clarke, W. H. Eckenbrine, Benj. Elkind, C. J. Henry, M. A. Michel, W. J. O'Connell, J. F. Piper, E. J. Sierleja, E. M. Skelton, J. J. Tibbits.

Your committee submits the following progress report as information.

Car Transfer Facilities

When the projected route of a railroad is confronted by an obstacle in the form of a river, lake or other body of water, and the construction of a bridge or tunnel is impractical or uneconomical, the only alternatives are to terminate the line at that point, attempt to go around the obstacle or to cross it by ship. In those instances where it is desirable to continue the route, but where the alternative of bypassing the obstacle cannot be considered because of distance, delay or the actual impossibility of doing so, the only choice left is to handle the traffic by vessel. In order to avoid shifting the freight from railroad car to ship and back again to railroad car, exposing

it to delay and loss and damage due to the rehandling, the car or train ferry was developed in the mid-1800's.

As a practical example of the above situation, several direct east-west rail routes are intersected by Lake Michigan, and while it would be possible to direct traffic by rail around the south end of the lake, to do so would involve additional expense because of the increased mileage and considerable delay due to the necessity of routing traffic through the Chicago area. The Lake Michigan car ferries were established near the end of the 19th century to handle this traffic, shortening the route by up to 180 miles and eliminating as much as two days delay.

Car ferry service can be separated into three main classes, as follows: (1) lake or ocean transfer by large sea-going vessels; (2) river transfer by steamers, motor vessels and barges; and (3) harbor transfer mainly by barges or car floats handled by tugboats. An additional, rather special, group consists of the long distance movements carried on between Cuba and the United States and between the east and gulf coasts.

The type of transfer facility to be provided for a car ferry depends on the physical conditions encountered, principally on the variation in water level. If a transfer bridge is used, the length is determined by the range of water level variation, the elevations at light and loaded draft of the loading decks of the vessels to be served, and the allowable grade of the bridge, which should be limited to approximately 6 percent. The bridge should be long enough to serve an empty vessel at the average high water and a fully loaded vessel at the average low water. The spacing and arrangement of the tracks to be provided on the transfer bridge will be determined by the size of the vessel's loading port and the track arrangement on the loading deck.

The most commonly used type of transfer bridge is an apron or span, from 50 to 100 ft in length, hinged at the shore end with the outer end suspended in such a way as to permit its being raised or lowered to the level of the vessel's loading deck. The suspension system can consist of hanger rods from rocking beams, counterweighted cables, hanger rods having threaded portions which ride in power-driven nuts on an overhead span, cables attached to overhead winches, hydraulic pistons, or pontoons with adjustable ballast tanks. This latter method of supporting and operating the outshore end of the bridge may be found unsatisfactory in locations subject to the formation of ice.

At locations where the changes in water level are too great to be compensated for by the adjustment and inclination of a single-span bridge, a multiple-span transfer bridge can be provided with all spans adjustable in elevation. The spans are all suspended from an overhead support and are usually so connected and operated that they form a unit structure, rotating on bearings at the shore end and having a continuous or uniform grade from the shore end to the outboard end. In this way a longer incline and easier grade can be provided while still being shorter than the incline and cradle system and avoiding a disadvantage of that system—that of having tracks and moving parts underwater.

As an alternative to providing an adjustable transfer bridge, the bridge can be fixed and the elevation of the vessel adjusted by berthing it in an enclosed dock equipped with a lock gate. While there are advantages to this method, the construction costs are considerably greater than for any other type of transfer facility.

Under certain conditions a single- or multiple-span transfer bridge may be unsatisfactory, as at a river crossing where the banks are wide and flat and the water level variation is great. The so-called cradle and incline method of transferring railroad cars to vessels has been developed to meet such conditions. It consists of an inclined track

extending diagonally down the bank on a trestle, and a platform, or cradle, having an ascending grade toward the water, riding on the incline. The ascending grade allows the length of the cradle to be reduced and prevents cars from getting away. The cradle is moved up or down the incline by a cable operated by a locomotive or a winch, so that the river end of its deck is always at the same elevation as the ship's deck. The grade of the incline is generally 3 percent descending and that of the cradle, 3 percent ascending.

A fourth type of transfer facility can be used for vessels on which cars are loaded through deck hatches and are carried on several decks. Such ships are presently in use only in the long distance movements where the speed of loading and unloading is not of first consideration and where comparatively large numbers of cars are transported per vessel. The installation consists of a crane having a traveling hoist or trolley and a cantilever extension projecting out over the ship. The railroad cars are run onto a cradle fitted into the tracks on the wharf, after which the cradle is raised by the hoist, run out on the extension, lowered through the deck hatch to the desired level where the car is moved off the cradle into its proper location on the deck track by a car puller. It is suggested that at least two cradle-equipped tracks be provided on the wharf to avoid delay in the operations. Installation of this type can be used only with marginal wharves, finger piers or slip-type wharves, and if the last is provided for berthing vessels, an overhead traveling crane can perhaps be used spanning the slip.

There are five general types of piers or berthing facilities, only three of which are satisfactory for use with car ferries of the conventional, or end loading, type. They are:

Finger piers—constructed out into the waterway either perpendicular to the shore line or at an acute angle. Where there is adequate depth and width of the waterway, these piers make the best advantage of a restricted waterfront and facilitate docking and unloading of large ships in strong currents. They are, however, susceptible to silting, and tugboats are usually required for docking vessels.

Slip-type wharves—perpendicular or acute angle indentures into the shoreline having the same advantages and disadvantages as finger piers, except that they can be used in waterways of less width.

Ferry slips—consisting usually of two lines of timber fender piling to form a berth, the inner or land end of which is shaped to fit the ship's stern to hold it steady and prevent lateral motion. The two lines of piling flare outward so as to guide the ship into position, but while one line is nearly the full length of the ship, the other, called the "knuckle", is much shorter. Docking at a ferry slip is quite rapid and tugboats are generally not required; however, adequate clearance is necessary in front of the slip to permit maneuvering.

As mentioned above, if vessels of the long-distance type are used, being loaded from the side through deck hatches, marginal wharves can be provided, as well as finger piers and slip-type wharves. Marginal wharves or quays are constructed parallel to the shoreline and are particularly applicable where the waterway is narrow. Docking is rapid and tugboats are not usually required since the ship can approach the wharf at an angle approximating its final position.

The construction and maintenance of car transfer facilities such as those described above will follow generally the practices used in other waterfront construction of comparable size. Permission must be obtained from the Corps of Engineers for construction in waterways coming under their jurisdiction and in some localities permits must also be obtained from dock or port authorities. Some municipalities have included in their building codes rules, regulations and recommended practices regarding the design and

construction of facilities of this type. For information on construction materials, the interested reader is referred to the report on Relative Merits and Economics of Construction Materials Used in Waterfront Facilities contained in the Proceedings, Vol. 59, 1958, pages 519 to 554, incl.

Recently there has been increased interest in the development of car ferries, or trainships as they are now designated, in order to eliminate the present time-consuming and expensive methods used to load and unload vessels. Designs have been produced for two-deck ships having the same capacity as four-track seatrains, with the advantage of being loaded from the ends over a relatively inexpensive transfer bridge, as compared with the expensive shore crane installation. However, even though the ships are undergoing changes in design, the information contained in this report remains applicable.

Report on Assignment 7

Relative Merits and Economics of Construction Materials Used in Water Front Facilities

S. T. Li (chairman, subcommittee), R. L. Bostian, Jr., C. M. Bowman, R. J. Clarke, A. F. Crowder, R. B. Midkiff, J. G. Roney, R. S. Rowe, C. R. Shaw, F. R. Spofford, J. J. Tibbitts, G. A. Wolf.

This selected bibliography on the adverse effects of the environment on, and preservation of, materials used in water front facilities has been compiled from the Engineering Guide, Readers Guide, and several random indices and lists at the Georgia Institute of Technology, for the period from 1951 to 1958.

The titles included in the bibliography were selected from descriptions given in the indices. Altogether there are 87 titles, classified below for easy reference. Although the list is not exhaustive, it is believed that it does constitute a basis for further studies on the subject.

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4. Wood

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Report of Committee 17—Wood Preservation

P. D. Brentlinger,
Chairman,
R. B. Radkey,
Vice Chairman,

A. B. Baker
W. W. Barger
R. S. Belcher (E)
W. S. Brown
Walter Buehler (E)
C. M. Burpee
C. S. Burt
G. B. Campbell
H. B. Carpenter
L. C. Collister
D. L. Davies
R. F. Dreitzler
H. R. Duncan
F. J. Fudge
W. H. Fulweiler
H. M. Harlow
B. D. Howe
M. S. Hudson
R. P. Hughes
H. E. Hurst
W. R. Jacobson
M. F. Jaeger*
W. L. Kahler
L. W. Kistler
A. J. Loom
P. B. Mayfield
T. H. Patrick
R. R. Poux
M. H. Priddy
W. C. Reichow
A. P. Richards
A. L. Simpson**
R. B. Smith
W. B. Stombock
F. H. Taylor
C. H. Wakefield
R. G. Zietlow

Committee

(E) Member Emeritus.
* Died October 6, 1957.
** Died May 21, 1958.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Specifications for wood preservatives.
   Progress report, presented as information ..... page 343

3. Specifications for petroleum as a carrier for standard wood preservatives.
   Progress report, including specification submitted for adoption ..... page 344

4. Specifications for preservative treatment of forest products, including laminated timbers, collaborating with Committees 6 and 7.
   Progress report, presented as information ..... page 345

5. Conditioning of wood before preservative treatment.
   No report.

7. Service test records of treated wood.
   Results of service tests of posts, submitted as information ..... page 347

8. Destruction by marine organisms, methods of prevention.
   Progress report, presented as information ..... page 372

9. Destruction by termites, methods of prevention, collaborating with Committees 6 and 7.

   Progress report on research project, presented in Bulletin 545, September–October 1958.

10. Incising forest products.

    No report.

THE COMMITTEE ON WOOD PRESERVATION,
P. D. BRENTLINGER, *Chairman*.

AREA Bulletin 547, December 1958.

MEMOIR

Arthur Leander Simpson

Arthur Leander Simpson, timber treatment engineer of the New York Central Railroad at its Toledo, Ohio, treating plant, passed away on May 21, 1958, following a heart attack. He is survived by his wife, Mrs. Elsie Sempler Simpson.

Mr. Simpson was born in Norwalk, Ohio, on September 3, 1895, and attended the University of Toledo. He entered the service of the New York Central as a clerk at the Toledo treating plant on July 1, 1923, progressing through all phases of work at the plant to the position of timber treatment engineer on April 1, 1947.

Mr. Simpson joined the AREA in 1957, becoming a member of Committee 17—Wood Preservation, in the same year. In addition to membership in the AREA, Mr. Simpson was also a member of the American Wood Preservers' Association and the Railway Tie Association.

Mr. Simpson was vitally interested in approved methods of wood preservation, and his dedication to duty will be sorely missed by his co-workers and many other friends.

F. J. FUDGE,
C. S. BURT,
R. B. RADKEY.

MEMOIR

M. F. Jaeger

M. F. Jaeger, superintendent of the Port Reading, N. J., Creosoting Plant, Reading Railroad, passed away on October 6, 1957.

"Martin", as he was known to his associates, received his grammar and high school education at Woodbridge, N. J., and later attended Rutgers University, School of Chemistry, New Brunswick, N. J. Prior to entering railroad employment, he was associated with the Woodbridge Lumber Company, Woodbridge. He entered railroad service with the Reading Company, January 25, 1915, as timekeeper, and was advanced to chief clerk at the Port Reading Creosoting Plant on August 1, 1916. On April 7, 1918, he was furloughed for service with the armed forces during World War I, in which he was actively engaged in combat in the front-line trenches in France, where he was wounded.

On June 16, 1919, Mr. Jaeger returned to the service of the Reading Company at the Port Reading Creosoting Plant. On September 1, 1929, he was promoted to superintendent of the plant, in which position he served until the time of his death.

Mr. Jaeger was a member of the Masonic order and the Presbyterian Church of Woodbridge. He served the Reading Railroad faithfully for many years, and contributed a great portion of his time to the affairs of Committee 17—Wood Preservation, of the American Railway Engineering Association. He became a member of this committee in 1931.

Martin was a faithful and diligent worker in connection with activities of this committee and gave generously of his time and ability to further its accomplishments. His good judgment, friendly manner and sincerity of purpose, which we were privileged to share for so many years, will be greatly missed. We deeply regret his passing and we will long remember his pleasing friendship.

C. S. Burt,
H. R. Duncan,
L. W. Kistler.

Report on Assignment 2

Specifications for Wood Preservatives

W. W. Barger (chairman, subcommittee), Walter Buehler, D. L. Davies, W. H. Fulweiler, M. S. Hudson, L. W. Kistler, P. B. Mayfield, T. H. Patrick, A. P. Richards, R. B. Smith.

As indicated in the following, the report on this assignment is made up of five parts, and is submitted as information only.

Part 1—Keep Up to Date Current Specifications for Preservatives

Your committee is of the opinion that our current specifications for preservatives are up to date at this time and require no changes.

Part 2—Review and Report on New Preservatives

Your committee has been studying the possibility of introducing osmosalts as a new preservative, but because of its similarity to other salt preservatives that are now standard, we suggest further study on this subject.

Part 3—Review Method of Sampling Creosote in Tank Cars

The committee is in favor of adopting part or all of the AWPA Standard Method of Sampling Wood Preservatives, A 4–56, as an AREA standard. Further study by the committee will be necessary before a definite decision can be made. The AWPA standard includes sampling of preservatives other than creosote in tank cars.

Part 4—Study the Advisability of Establishing the Flash Point of Creosote

Your committee is of the opinion that the establishment of the flash point of creosote is not necessary at this time and recommends that this part of the assignment be dropped.

Part 5—Review "Comments" after Preservative Specifications; Report on Need For Comments with a View Toward Continuance, Deletion, or Change of Title

The committee has continued to study this subject but has not come to a definite decision as to whether the comment should be retained, dropped or edited. Further study is recommended.

Report on Assignment 3

Specifications for Petroleum as a Carrier for Standard Wood Preservatives

T. H. Patrick (chairman, subcommittee), W. W. Barger, H. B. Carpenter, L. C. Collister, R. F. Dreitzler, H. R. Duncan, C. H. Wakefield, R. G. Zeitlow.

Your committee submits the following report of progress, with specifications recommended for adoption.

Part 1—Keep Up to Date Specifications for Petroleum

We have reviewed our specifications for petroleum for blending with creosote and have given consideration to changing the flash point of 215 deg F to a lower figure as the specifications of other associations now provide. However, the committee finds no hardship is entailed in holding the minimum flash point to 215 deg F; if it were lowered some undesirable oils may be furnished. A distillation requirement was considered but no decision was reached. We do not recommend any change to our present specifications at this time.

Part 2—Prepare a Specification for Petroleum for Blending with Pentachlorophenol

Pentachlorophenol is in considerable use, and as a guide some standard is needed for the petroleum used as the solvent. While it is felt that there will be information developed in the future that will permit writing a better specification, to cover our present needs, we propose a specification based on our present knowledge. It is similar to that of other association, and can be added to or changed as more desirable characteristics are found advisable. This specification is presented herewith, and your committee recommends that it be adopted and published in the manual.

PETROLEUM SOLVENT FOR PENTACHLOROPHENOL

Petroleum as a solvent for pentachlorophenol shall conform to the following requirements:

Specific gravity at 60 deg F not less than 0.85 (not greater than 35 API). ASTM D 287.

Water and sediment BS&W, not more than 0.5 percent. ASTM D 96.

Flash point not less than 175 deg F as determined by Pensky–Martens closed tester. ASTM D 93.

Distillation range shall be as follows as determined by ASTM Method D 158:

50-percent point not lower than 500 deg F (260 deg C).
90-percent point not lower than 600 deg F (315.5 deg C).

The viscosity shall be not less than 30 sec and not more than 60 sec, although oils of a higher viscosity may be used, provided that penetration requirements are met. The purchaser may specify the viscosity best suited to his requirements, allowing the supplier a tolerance of plus or minus 10 percent of the value specified. Viscosity shall be in terms of Saybolt Universal Seconds at 210 deg F. ASTM D 88.

The petroleum shall dissolve at least 10 percent by weight of pentachlorophenol at 75 deg F.

Test to determine the foregoing requirements shall be made in accordance with the ASTM method currently in effect. The ASTM standards referred to may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Report on Assignment 4

Specifications for Preservative Treatment of Forest Products, Including Laminated Timbers

Collaborating with Committees 6 and 7

L. C. Collister (chairman, subcommittee), P. D. Brentlinger, C. S. Burt, D. L. Davies, R. F. Dreitzler, H. R. Duncan, F. J. Fudge, W. L. Kahler, P. B. Mayfield, T. H. Patrick, R. R. Poux, R. B. Radkey, W. C. Reichow, A. L. Simpson.

This is a progress report, presented as information.

At the committee meeting on March 12 it was brought out that the treatment of Tc and Td cross and switch ties should be investigated. Refusal is to high for certain species, causing unnecessary waste and expense.

In reviewing the species classified as Td, it will be noted that the heart sections of some of these trees are included in Group Ud, namely, the catalpas, chestnut, sassafras and red mulberry. The other species—ashes, beech, birches, cherries, elms, hackberries, hickories, hard maples, soft maples, poplars, sycamores and white walnut—treat pretty much alike and can be easily loaded with preservative. Therefore, it is recommended that the Td species, as listed, be treated to 9 lb retention as indicated on the accompanying table (see next page).

Since we could not reach an agreement for a definition for "Refusal point" and "Refusal treatment", this will be given further study.

Cross Ties and Switch Ties

	AREA-Td
CONDITIONING	Air-seasoning, accelerated air-seasoning, or heating in the preservative, or a combination.
Steaming	Not Permitted
Temp.--deg F--max	
Vacuum	
Inches at sea level--min	22
Duration min	
max	
Heating in preservative	
Temp.--deg F--max	220
Duration	Optional
Incising	As specified
TREATMENT	
Creosote-type preservatives	Empty-cell
Pressure--psi--min	
max	200
RESULTS OF TREATMENT	
Retention--lbs per cu ft--min	
Creosote-type preservatives	
Creosote	9
Creosote-coal tar	9
Creosote-petroleum	9
Penetration in inches or percent of sapwood--min	95% of sapwood
Determination of penetration	A borer core shall be taken from the center of 20 ties in each charge. If 80% of the cores meet the penetration requirements the charge shall be accepted.

Report on Assignment 7

Service Test Records of Treated Wood

R. P. Hughes (chairman, subcommittee), A. B. Baker, W. S. Brown, C. M. Burpee, L. W. Kistler, R. R. Poux, R. B. Radkey, W. C. Reichow, W. B. Stombock, F. H. Taylor.

Your committee submits the following reports on service test records of treated wood:

1. Report on 1958 inspection of Atchison, Topeka & Santa Fe Railway's treated fence post test at Cleveland, Tex.
2. Report of 1955 inspection of treated fence posts in right-of-way fence of Missouri–Kansas–Texas Railroad between South Canadian River and Canadian, Okla.
3. Report of 1957 inspection of treated fence posts in fence line on Lars Friesth farm near Humboldt, Iowa, by Wood Preserving Division, International Paper Company.
4. Comparison of wood preservatives in Mississippi post study, 1958 Progress Report, by J. Oscar Blew, Jr., Technologist, and John W. Kulp, Technologist, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.

POST SERVICE RECORDS

A. T. and S. F. Ry. Co. - Cleveland, Texas

Posts are Round Southern Pine 3-1/2" to 5" top diameter, and placed in wet, sandy soil.

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
14	German Creosote	5.00	10-1913	22	12-1957	1-1954 1-1957	Decay "	2	9.1	43.9
15	German Creosote	26.75	10-1913	17	12-1957	None		0	0.0	44.0
40	Wolman Salts (Triolith)	.514	6-1929	25	2-1947	2-1936 4-1937 1-1938 7-1940 4-1943 1-1944 6-1947	Decay & Termites " " " " " " " " " " " "	25	100.0	12.4
41	Wolman Salts (Triolith)	.303	6-1929	24	2-1947	2-1936 8-1937 2-1939 9-1940 1-1943 2-1947	Decay & Termites " " " " " " " " " "	24	100.0	10.3
42	Wolman Salts (Triolith) followed by Petroleum	Salt .461 Petr.8.78	6-1929	10	12-1957	2-1947	Decay	2	20.0	26.0
43	Wolman Salts (Triolith) followed by Petroleum	Salt .333 Petr.9.62	6-1929	10	12-1957	None		0	0.0	28.0
45	Creosote	24.48	10-1928	15	12-1957	None		0	0.00	29.0
46	Creosote	7.99	10-1928	15	12-1957	1-1952	Decay	1	6.7	28.5
47	Creosote	5.26	10-1928	15	12-1957	1-1937 2-1952 1-1954 1-1957	Disappeared Decay " "	5	33.3	26.8

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
48	70% Creosote 30% Petroleum	25.04	10-1928	15	12-1957	None		0	0.0	29.0
49	70% Creosote 30% Petroleum	7.84	10-1928	15	12-1957	None		0	0.0	29.0
50	70% Creosote 30% Petroleum	5.08	10-1928	15	12-1957	None		0	0.0	29.0
51	60% Creosote 40% Petroleum	23.21	10-1928	15	12-1957	None		0	0.0	29.0
52	60% Creosote 40% Petroleum	7.92	10-1928	15	12-1957	None		0	0.0	29.0
53	60% Creosote 40% Petroleum	5.32	10-1928	15	12-1957	2-1950 1-1952 3-1954 1-1957	Decay " " "	7	47.0	27.1
54	50% Creosote 50% Petroleum	26.32	10-1928	14	12-1957	None		0	0.0	29.0
55	50% Creosote 50% Petroleum	7.83	10-1928	15	12-1957	None		0	0.0	29.0
56	50% Creosote 50% Petroleum	5.22	10-1928	15	12-1957	1-1950 1-1952 1-1954	Decay " "	3	20.0	28.0
57	40% Creosote 60% Petroleum	23.38	10-1928	15	12-1957	None		0	0.0	29.0
58	40% Creosote 60% Petroleum	7.00	10-1928	15	12-1957	1-1950	Decay	1	6.7	28.5
59	40% Creosote 60% Petroleum	5.43	10-1928	10	12-1957	1-1952 1-1954	Decay "	2	13.3	28.2
60	25% Creosote 75% Petroleum	20.29	10-1928	15	12-1957	None		0	0.0	29.0
61	25% Creosote 75% Petroleum	7.89	10-1928	15	12-1957	1-1950	Decay	1	6.7	28.5
62	25% Creosote 75% Petroleum	5.19	10-1928	15	12-1957	1-1943 1-1947 6-1950 2-1952 3-1954 1-1957	Decay " " " " "	14	93.3	23.3

POST SERVICE RECORDS - A. T. and S. F. Ry. Co. - Cleveland, Texas. -3-

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
63	10% Creosote 90% Petroleum	23.22	10-1928	15	12-1957	None		0	0.0	29.0
64	10% Creosote 90% Petroleum	8.08	10-1928	15	12-1957	1-1937 1-1954 2-1957	Disappeared Decay "	4	26.7	27.5
65	10% Creosote 90% Petroleum	5.16	10-1928	15	12-1957	1-1940 3-1950 2-1952 1-1957	Decay " " "	7	46.7	25.8
66	70% Creosote 30% Coal Tar	23.79	10-1928	10	12-1957	None		0	0.0	29.0
67	70% Creosote 30% Coal Tar	27.07	10-1928	15	12-1957	None		0	0.0	29.0
68	70% Creosote 30% Coal Tar	8.13	10-1928	15	12-1957	None		0	0.0	29.0
69	70% Creosote 30% Coal Tar	4.88	10-1928	16	12-1957	1-1950 1-1952 1-1954 2-1957	Decay " " "	5	33.3	28.1
70	60% Creosote 40% Coal Tar	24.77	10-1928	15	12-1957	None		0	0.0	29.0
71	60% Creosote 40% Coal Tar	8.07	10-1928	15	12-1957	None		0	0.0	29.0
72	60% Creosote 40% Coal Tar	5.26	10-1928	16	12-1957	None		0	0.0	29.0
73	50% Creosote 50% Coal Tar	24.36	10-1928	10	12-1957	None		0	0.0	29.0
74	50% Creosote 50% Coal Tar	27.35	10-1928	15	12-1957	None		0	0.0	29.0
75	50% Creosote 50% Coal Tar	8.08	10-1928	15	12-1957	1-1952	Decay	1	6.7	28.7
76	50% Creosote 50% Coal Tar	5.14	10-1928	15	12-1957	3-1954 3-1957	Decay "	6	40.0	28.4
77	40% Creosote 60% Coal Tar	28.76	10-1928	10	12-1957	None		0	0.0	29.0

POST SERVICE RECORDS - A. T. and S. F. Ry. Co. - Cleveland, Texas

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
78	40% Creosote 60% Coal Tar	26.07	10-1928	15	12-1957	None		0	0.0	29.0
79	40% Creosote 60% Coal Tar	8.29	10-1928	15	12-1957	1-1950 1-1954	Decay "	2	13.3	28.3
80	40% Creosote 60% Coal Tar	5.44	10-1928	15	12-1957	1-1947 1-1952 2-1954 1-1957	Disappeared Decay " "	5	33.3	27.6
81	25% Creosote 75% Coal Tar	28.14	10-1928	15	12-1957	None		0	0.0	29.0
82	25% Creosote 75% Coal Tar	7.92	10-1928	14	12-1957	2-1947 1-1950 2-1952	Decay " "	5	35.7	26.4
83	25% Creosote 75% Coal Tar	5.31	10-1928	15	12-1957	2-1947 3-1952 2-1957	Decay " "	7	46.7	26.7
84	10% Creosote 90% Coal Tar	27.07	10-1928	15	12-1957	None		0	0.0	29.0
85	10% Creosote 90% Coal Tar	8.06	10-1928	15	12-1957	1-1952 1-1954 1-1957	Decay " "	3	20.0	28.5
86	10% Creosote 90% Coal Tar	5.18	10-1928	15	12-1957	2-1947 6-1952 1-1954	Decay " "	9	60.0	25.5
87	Arsenicated Petroleum	4.90	4-1931	15	3-1952	3-1943 9-1947 2-1950 1-1952	Decay " " "	15	100.0	15.9

POST SERVICE RECORDS - A. T. and S. F. Ry. Co. - Cleveland, Texas -5-

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.-Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
88	Petroleum	4.75	4-1931	15	12-1954	1-1935 2-1937 1-1940 3-1943 5-1947 2-1950 1-1954	Decay " " " " " Still in Service	15	100.0	13.5
89	Arsenicated Gas Oil	7.71	11-1935	15	12-1957	2-1954	Decay	2	13.3	21.6
95	5% Pentachlorophenol in Gas Oil (4"x4"x4' S. Pine)	11.19	2-1938	15	12-1957	None		0	0.0	19.0
96	4.9% Pentachlorophenol in Gas Oil	4.98	2-1938	9	12-1957	None		0	0.0	19.0
97	4.9% Pentachlorophenol in Gas Oil	8.30	2-1938	10	12-1957	None		0	0.0	19.0
98	3% Zinc Chloride Solution	.53	3-1940	10	12-1957	1-1947 1-1950 2-1952 3-1954 2-1957	Decay " " " Decay & Termites	9	90.0	13.4
99	2.5% Chromated Zinc Chloride Solution	.43	3-1940	10	12-1957	2-1943 2-1947 1-1952 3-1954 2-1957	Decay " " " "	10	100.0	10.8
100	4.3% Zinc Chloride Solution	.74	3-1940	10	12-1957	1-1950 3-1954	Decay "	4	40.0	15.4
101	4% Chromated Zinc Chloride Solution	.74	3-1940	10	12-1957	3-1943 2-1947 3-1952 2-1957	Decay " " "	10	100.0	9.3

POST SERVICE RECORDS - A. T. and S. F. Ry. Co. - Cleveland, Texas

Group No.	Preservative	Absorp. Lbs. Per Cu.Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year	Cause	Removed Number	Removed Per Cent	Average Life to Date
102	5.4% Zinc Chloride Solution	1.06	3-1940	10	12-1957	2-1952 2-1957	Decay "	4	40.0	16.0
103	5.5% Chromated Zinc Chloride Solution	1.01	3-1940	10	12-1957	3-1947 2-1950 1-1952 3-1957	Decay " " "	9	90.0	12.1
104	7% Zinc Chloride Solution	1.25	3-1940	10	12-1957	2-1957	Decay	2	20.0	17.0
105	7% Chromated Zinc Chloride Solution	1.25	3-1940	10	12-1957	1-1947 1-1950 1-1952 2-1957	Decay " " Decay & Termites	5	50.0	14.8
122	Solution of 50% Gas Oil - 50% Residuum Oil with 5% (Dry Pentachlorophenol added (Salt	6.88 .344	7-1947	10	12-1957	None		0	0.0	10.0
123	Solution of 50% Gas Oil - 50% Residuum Oil with 5% (Dry Pentachlorophenol added (Salt	8.31 .416	7-1947	10	12-1957	None		0	0.0	10.0
124	Solution of 50% Gas Oil - 50% Residuum Oil with 5% (Dry Copper Napthenate Added (Salt	5.82 .291	7-1947	10	12-1957	None		0	0.0	10.0
125	Solution of 50% Gas Oil - 50% Residuum Oil with 5% (Dry Copper Napthenate added (Salt	8.87 .444	7-1947	10	12-1957	None		0	0.0	10.0
126	Solution of 5% Copper Napthenate in Gas Oil (Dry Salt.	5.29 265)	11-1947	10	12-1957	None		0	0.0	10.0
127	Solution of 5% Copper Napthenate in Gas Oil (Dry Salt.	7.50 376)	11-1947	10	12-1957	None		0	0.0	10.0
129	Solution of 2% Thanite in Gas Oil	5.42	10-1948	10	12-1957	None		0	0.0	9.0

POST SERVICE RECORDS - A. T. and S. F. Ry. Co. - Cleveland, Texas -7-

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year Cause	Removed Number	Removed Per Cent	Average Life to Date
130	Solution of 2% Thanite in Gas Oil	8.64	10-1948	10	12-1957	None	0	0.0	9.0
131	Solution of 2% Thanite in Gas Oil	25.33	10-1948	10	12-1957	None	0	0.0	9.0
132	Solution of 5% Thanite In Gas Oil	5.05	10-1948	10	12-1957	2-1954 Decay & Termites 1-1957 " "	3	30.0	8.4
133	Solution of 5% Thanite in Gas Oil	8.12	10-1948	10	12-1957	None	0	0.0	9.0
134	Solution of 5% Thanite in Gas Oil	27.56	10-1948	10	12-1957	None	0	0.0	9.0
135	Solution of 2% Rosin Amine D in Gas Oil	5.94	10-1948	10	12-1957	None	0	0.0	9.0
136	Solution of 2% Rosin Amine D in Gas Oil	8.23	10-1948	10	12-1957	None	0	0.0	9.0
137	Solution of 2% Rosin Amine D in Gas Oil	24.9	10-1948	10	12-1957	None	0	0.0	9.0
138	Solution of 5% Rosin Amine D in Gas Oil	5.5	10-1948	10	12-1957	None	0	0.0	9.0
139	Solution of 5% Rosin Amine D in Gas Oil	8.4	10-1948	10	12-1957	None	0	0.0	9.0
140	Solution of 5% Rosin Amine D in Gas Oil	26.1	10-1948	10	12-1957	None	0	0.0	9.0
141	Solution of 2% Thanite in Residuum Oil	5.93	10-1948	10	12-1957	None	0	0.0	9.0
142	Solution of 2% Thanite in Residuum Oil	8.66	10-1948	10	12-1957	None	0	0.0	9.0
143	Solution of 2% Thanite in Residuum Oil	22.8	10-1948	10	12-1957	None	0	0.0	9.0

Group No.	Preservative	Absorp. Lbs. Per Cu. Ft.	Date Set	Number In Test	Date Last Insp.	Removed or Unserviceable No.&Year Cause	Removed Number	Removed Per Cent	Average Life to Date
144	Solution of 5% Thanite in Residuum Oil	6.02	10-1948	10	12-1957	None	0	0.0	9.0
145	Solution of 5% Thanite In Residuum Oil	8.7	10-1948	10	12-1957	None	0	0.0	9.0
146	Solution of 5% Thanite in Residuum Oil	22.4	10-1948	10	12-1957	None	0	0.0	9.0
147	Solution of 2% Rosin Amine D in Residuum Oil	5.3	10-1948	10	12-1957	None	0	0.0	9.0
148	Solution of 2% Rosin Amine D in Residuum Oil	9.0	10-1948	10	12-1957	None	0	0.0	9.0
149	Solution of 2% Rosin Amine D in Residuum Oil	21.75	10-1948	10	12-1957	None	0	0.0	9.0
150	Solution of 5% Rosin Amine D in Residuum Oil	5.33	10-1948	10	12-1957	None	0	0.0	9.0
151	Solution of 5% Rosin Amine D in Residuum Oil	7.13	10-1948	10	12-1957	None	0	0.0	9.0
152	Solution of 5% Rosin Amine D in Residuum Oil	25.66	10-1948	10	12-1957	None	0	0.0	9.0

Report of 1955 Inspection of Treated Fence Posts, Right-of-way Fence, Missouri-Kansas-Texas Railroad, Between the South Canadian River and Canadian, Okla.

Location—M.P. 543.4—M.P. 547.2
Original Number Inserted—2,200 (approximately)
Kind of Wood—Southern yellow pine
Treatment—Empty cell process—6 lb per cu ft, AREA specification creosote
Date of Insertion—1923
Date of Last Inspection—1955
Number of Posts Removed—7
Cause of Removal—Apparently for driveway
Number of Posts Remaining—2,193 (approximately)
Average Life of Posts—36 years
Expected Average Life—46 years

Report of 1957 Inspection of Treated Posts in Fence Line on Lars Friesth Farm Near Humboldt, Iowa, by Wood Preserving Division, International Paper Company

Kind of Wood—Southern yellow pine
Number—175 6½-ft round line posts
Condition Before Treatment—dry
Conditioning Used—Air seasoning
Treatment—Lowry process
Date of Treatment and Installation—1917
Preservative—80/20 creosote-coal tar mixture
Net Retention of Preservative—6 lb per cu ft
Penetration of Preservative—Good, complete
Date of Inspection and Method—June 1957, visual
Causes for and Number of Removals—All 175 still in sound condition, no failures
Decay—None
Wood Defects—None
Structural Breakdown in Wood—None
Mechanical Damage—None
Obsolescence—None

Views of three fence posts in M–K–T right-of-way fence between the South Canadian River and Canadian, Okla. Treated with AREA specification creosote, 6 lb per cu ft. Life to date, 36 years.

Comparison of Wood Preservatives in Mississippi Post Study

(1958 Progress Report)

By J. Oscar Blew, Jr., and John W. Kulp

Technologists, Forest Products Laboratory,[1] Forest Service
U. S. Department of Agriculture

Summary

Experimental untreated southern yellow pine posts installed from 1936 to 1938 at the Harrison Experimental Forest, Saucier, Miss., had an average life of 3.3 years. Untreated longleaf pine posts installed in 1949 had an average life of 2.3 years, while those treated with a No. 2 fuel oil and with Wyoming residual petroleum oil have an estimated average life of 7 and 8 years, respectively. Of southern yellow pine posts installed from 1936 to 1941, those treated with borax-boric acid have all failed after 20 years of service. Their average life was 10.6 years. Posts treated with the following preservatives have had failures totaling less than 10 percent of the number installed and should last 32 years or longer on an average: water gas tar; 50–50 solution or creosote–crankcase oil; tetrachlorophenol, 4.8 percent in crankcase oil; pentachlorophenol, 3 percent and 4.8 percent in crankcase oil; copper sulfate and sodium arsenate applied by double diffusion; and zinc meta arsenite. Posts in test in 1936 to 1941 treated with other preservatives have an estimated average life of 13 to 32 years.

Introduction

During late 1936 and early 1937, the U. S. Forest Products Laboratory, in cooperation with the Southern Forest Experiment Station and the then existing Bureau of Entomology and Plant Quarantine, started a service test at the Harrison Experimental Forest, Saucier, Miss., on posts treated with 24 wood preservatives. A report by Wirka[2] contained a description of the preservatives and treatments used in the original installation of posts in a line approximately 8 miles long. This report also described the installation and presented the results of the test after 3 years of service. Additional posts were added to this line during the years 1938 and 1941. A report by Blew[3] in 1947 described these additions and presented the condition of all posts in the 8-mile line after approximately 5½ to 10 years of service. During April and May 1949 the study was expanded to include posts treated with 44 preservatives and untreated controls that were installed in a plot on the Harrison Experimental Forest. Various commercial companies cooperated in this work by furnishing the preservatives and by contributing to the cost of making the treatments and of installing test posts. Annual progress reports[4] issued since 1950 describe the condition of the posts in the two installations.

This progress report deals with the condition of the posts at the time of the December 1957 inspection, or after 16½ to 21 years of service in the line, and after 8½ years in the plot installation. The report also briefly describes the materials and treatments used and the procedure followed in inspecting the posts.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Wirka, R. M. Comparison of Preservatives in Mississippi Fence-Post Study. Proceedings of the American Wood-Preservers' Association, 1941, pp. 365–379.

[3] Blew, J. O. Comparison of Preservatives in Mississippi Fence-Post Study After 10 Years of Service. Proceedings of the American Wood-Preservers' Association, 1947, pp. 26–41.

[4] Blew, J. O., and Kulp, John W. Comparison of Wood Preservatives in Mississippi Post Study (1957 Progress Report). Forest Products Laboratory Report No. 1757, January 1957.

Posts

All of the posts used in this study were of round southern yellow pine that consisted mostly of sapwood. Those treated in 1941 with Osmoplastic and by double diffusion were cut and treated while green on the Harrison Experimental Forest. All other posts were cut at McNeill, Miss., and were shipped to the Forest Products Laboratory for treatment. The posts to be treated with Osmosar were freshly cut and shipped green; the others were peeled, sprayed with stain-control chemical, and air-dried before shipment. The posts installed in the line from 1936 to 1941 were 7 ft in length and from 2½ to 7 in. in top diameter. Those installed in the plot during 1949 were of longleaf pine 6 ft in length and from 2.8 to 5.3 in. in top diameter. These posts were peeled, dipped in a stain-control chemical, and shipped to the Laboratory for air or kiln drying. Many of them required repeeling, before treatment, to remove inner bark. The different diameter sizes were distributed as uniformly as practicable to each of the treatments used in the study.

Preservatives and Treatment

Tables 1 and 2 show the preservatives used. Table 1 includes 26 preservatives or treatments and also untreated control posts set in the line from 1936 to 1941. Forty-four preservatives or treatments and untreated control posts are included in Table 2 for the posts set in the plot during 1949.

In the line installation are included four non-pressure treatments: Steeping with mercuric chloride; full-length osmose treatment of green posts with Osmosar; treatment at the groundline and at the immediate tops of the posts with Osmoplastic; and full-length double-diffusion treatment of green posts with copper sulfate and sodium arsenate. The remaining treatments in the line installation and all treatments in the plot installation were by pressure impregnation. In the pressure treatments, the oils were applied by the Rueping empty-cell process, and the water-borne preservatives were applied by the full-cell process.

Minimum, maximum, and average preservative retentions are shown in Tables 1 and 2. Borings taken from posts following each pressure treatment showed, for the most part, either complete or nearly complete penetration of the sapwood. Exceptions were noted, however, in the posts pressure-treated for the 1936 installation with coal tar, with 10 percent of coal-tar creosote and 90 percent of used crankcase oil, with lignite coal-tar creosote, with water-gas tar, and with No–D–K (hardwood–tar creosote). In these treatments, a high percentage of the posts bored showed penetrations of less than 60 percent of the sapwood depth. Borings taken from the posts treated by steeping in mercuric chloride all showed poor penetration of the preservative. Penetration measurements were not made on the posts treated with Osmosar, those treated by double diffusion, or those treated with Osmoplastic.

Installation of Posts

The posts, at the start of the test, were set from late 1936 until February 1937 in a line approximately 8 miles long on the Harrison Experimental Forest, Saucier, Miss. The posts were grouped into 100 units, each of which included 1 post of the different treatments selected at random, and, for the most part, 1 untreated control post. It was possible to install only 65 untreated posts at the same time the treated posts were installed, and the remaining 33 were set during November and December 1938. The position of the treated posts and of the untreated control post within each unit was also randomized. During 1941, two additional treatments were added to this line, with 1 post from each treatment being installed in each of the 100 units. The

(Text continued on page 364)

Table 1.--Condition of round southern yellow pine experimental fence posts on the Harrison Experimental Forest, Saucier, Miss., after about 16-1/2 to 21 years of service (treated posts were installed from late in 1936 to May 1941)

Preservative	Posts in test[1]	Form of preservative	Retention of preservative[2]				Method of treatment	Condition of posts, December 1957				Total removed	Average life[3]
			Minimum	Maximum	Average	Standard deviation		Serviceable	Removed because of				
									Decay	Decay, termites	Termites		
	No.		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	No.	Percent	Yr.
Posts set late in 1936 to February 1937														
Beta-naphthol, 5 percent (by weight) in oil mixture	98	Solution	3.90	10.00	6.20	1.30	Pressure	6.1	18.4	56.1	19.4	92	93.9	16
Borax-boric acid (50-50 mixture)	97	Salt	.64	1.32	.92	.11	...do...		17.5	46.4	36.1	97	100.0	10.6
Celcure (acid copper chromate)	88	...do...	.75	1.05	.92	.08	...do...	82.9	14.8	2.3		15	17.1	30
Chromated zinc chloride	96	...do...	.37	1.33	.87	.19	...do...	59.4	21.9	18.7		39	40.6	24
Coal tar	95	Oil	1.60	19.20	6.50	2.90	...do...	80.0	8.4	11.6		19	20.0	28
Coal-tar creosote, grade 1	95	...do...	1.90	8.60	6.00	1.50	...do...	89.5	10.5			10	10.5	32
Coal-tar creosote, 50 percent used crankcase oil, 50 percent (by volume)	98	Solution	1.60	14.80	5.40	2.20	...do...	92.9	7.1			7	7.1	
Coal-tar creosote, 10 percent, used crankcase oil, 90 percent (by volume)	99	...do...	.10	23.20	7.10	3.80	...do...	25.2	66.7	7.1	1.0	74	74.8	19
Crankcase oil (used)	97	Oil	2.50	16.80	7.60	2.90	...do...	10.3	85.6	4.1		87	89.7	17
Lignite coal-tar creosote	97	...do...	1.10	11.60	6.30	3.20	...do...	60.8	16.5	19.6	3.1	38	39.2	24
Mercuric chloride	100	Salt	.05	.15	.09	.03	Steeping	62.0	8.0	21.0	9.0	38	38.0	24
No-D-K (hardwood-tar creosote)	100	Oil	1.30	13.60	6.60[4]	3.50	Pressure	38.0	17.0	41.0	4.0	62	62.0	21
Osmosar	96	Salt			.30[4]		Osmose	54.2	20.8	18.8	6.2	44	45.8	23
P.D.A. (phenyldichlorarsine) 0.84 percent in gas oil (by weight)	94	Solution	4.10	11.00	5.90	.90	Pressure	39.3	8.5	39.4	12.8	57	60.7	21
Pentachlorophenol, 4.82 percent (by weight) in used crankcase oil	97	...do...	2.90	9.50	6.70	1.60	...do...	99.0	1.0			1	1.0	
Pentachlorophenol, 3.02 percent (by weight) in used crankcase oil	92	...do...	3.10	11.40	6.40	1.80	...do...	96.7	3.3			3	3.3	
Sodium dichromate	97	Salt	.59	1.14	.88	.11	...do...	26.8	6.2	29.9	37.1	71	73.2	19

Table 1.--Condition of round southern yellow pine experimental fence posts on the Harrison Experimental Forest, Saucier, Miss., (Cont'd) after about 16-1/2 to 21 years of service (treated posts were installed from late in 1936 to May 1941)

Preservative	Posts in test[1]	Form of preservative	Retention of preservative[2]				Method of treatment	Condition of posts, December 1957				Total removed		Average life[3]
			Minimum	Maximum	Average	Standard deviation		Serviceable	Removed because of					
									Decay	Decay, termites	Termites			
	No.		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	Percent	No.	Percent	Yr.
Sodium chromate	88	...do....	.70	1.19	.93	.10	...do....	25.0	5.7	21.6	47.7		66	75.0	19
Wolman salt (Tanalith)	97	...do....	.20	.47	.35	.07	...do....	65.0	18.5	11.3	5.2		34	35.0	25
Tetrachlorophenol, 2.9 percent (by weight) in used crankcase oil	92	Solution	1.20	16.10	7.10	3.10	...do....	87.0	13.0				12	13.0	31
Tetrachlorophenol, 4.83 percent (by weight) in used crankcase oil	94	...do....	3.50	9.40	5.80	1.50	...do....	93.6	5.3	1.1			6	6.4	.....
Water-gas tar	93	Oil	1.20	19.00	6.30	3.00	...do....	92.5	6.4	1.1			7	7.5	.....
Zinc chloride	96	Salt	.67	1.11	.94	.10	...do....	64.6	15.6	19.8			34	35.4	25
Zinc meta arsenite	95	...do....	.25	.54	.42	.06	...do....	99.0	1.0				1	1.0	.....
Untreated posts (set Feb. 1937)	65						None		3.1	93.8	3.1		65	100.0	3.1
Posts set in 1938 and 1941															
Untreated posts (set Nov., Dec. 1938)	33						None		33.3	63.6	3.1		33	100.0	3.7
Copper sulfate and sodium arsenate (set May 1941)	98	Salt			(.35 (.16		Double diffusion	98.0	2.0				2	2.0	.....
Osmoplaetic ground-line treatment (set Feb. 1941)	99	Mixture			[5] .34		(5)	5.1	27.3	54.5	13.1		94	94.9	13

[1] Installations included 100 posts for each treatment. This number has since been reduced in some cases by fire and pilferage.

[2] Based on the 100 posts treated in each group, unless otherwise indicated.

[3] Average life of all untreated posts is 3.3 years; average life shown where all posts have been removed and other values are estimates taken from a mortality curve. Where percentage of posts removed is 10 percent or less, no estimate on average life is given.

[4] Average application.

[5] Average application per post to a 15-inch band (3 inches above and 12 inches below ground line) and to top surface of post.

Table 2.--Condition of round longleaf pine experimental posts on the Harrison Experimental Forest, Saucier, Miss., after about 8-1/2 years of service. (All treatments by pressure impregnation. Posts were installed during April and May 1949.)

Preservative	Posts in test	Form of preservative	Retention of preservative: Minimum	Maximum	Average	Standard deviation	Serviceable	Condition of posts, December 1957: Removed because of: Decay	Decay, termites	Termites	Total removed	Average life[1]
	Number		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	Number	Percent	Yr.
Boliden salt A (H_3AsO_4 + Na_2HAsO_4 + $Na_2Cr_2O_7.2H_2O$ + $ZnSO_4$)	25	Dry salt	0.65	0.76	0.70	0.029	96.0	4.0			1	4.0	
Boliden salt B (ZnO + H_3AsO_4 + CrO_3)	25	do.	.43	.57	.50	.035	100.0						
Carbosota (coal-tar creosote)	25	Oil	5.2	6.9	6.0	.593	100.0						
Chemonite (ammoniacal copper arsenite)	25	Dry salt	.30	.39	.34	.029	100.0						
Chromated zinc chloride, copperized ($ZnCl_2$ + $Na_2Cr_2O_7.2H_2O$ + $CuCl_2.2H_2O$)	25	do.	.89	1.06	.98	.055	92.0	8.0			2	8.0	
Chromated zinc chloride, FR ($ZnCl_2$ + $Na_2Cr_2O_7.2H_2O$ + B_3BO_3 + $(NH_4)_2SO_4$)	25	do.	2.71	3.59	3.25	.254	100.0						
Coal-tar creosote:													
Straight run, low residue	25	Oil	4.6	7.5	5.9	.903	100.0						
Straight run, medium residue	25	do.	4.2	7.7	5.6	.899	100.0						
Straight run, high residue	25	do.	4.9	7.5	6.0	.873	100.0						
Medium residue, low in tar acids	25	do.	4.6	6.9	5.7	.638	100.0						
Medium residue, low in naphthalene	25	do.	5.2	7.1	6.1	.519	100.0						
Medium residue, low in tar acids and naphthalene	25	do.	4.8	7.6	6.0	.701	100.0						
Low residue, low in tar acids and naphthalene	25	do.	5.3	6.9	6.0	.516	100.0						
High residue, low in tar acids and naphthalene	25	do.	5.4	6.8	6.1	.399	100.0						
Medium residue, low in fraction from 235° to 270° C., crystals removed	25	do.	5.1	7.0	6.1	.591	100.0						
High residue, crystals removed	25	do.	5.1	6.8	6.0	.528	100.0						
Low temperature	25	do.	5.5	6.9	6.3	.401	100.0						
English, vertical retort	25	do.	5.0	6.9	6.3	.552	100.0						
English, coke oven	25	do.	4.5	7.4	6.0	.715	100.0						
English, vertical retort 50% and coke oven 50% (by volume)	25	Solution	5.2	6.8	6.0	.489	100.0						
Medium residue (low in tar acids and naphthalene) with 2-1/2% pentachlorophenol (by weight)	25	do.	5.1	6.9	6.0	.594	100.0						
Coal-tar creosote 70%, and coal-tar 30% (by volume)	25	do.	5.2	6.9	6.1	.574	100.0						
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (No. 2 distillate) 50% (by volume)	25	do.	5.2	6.8	5.9	.418	100.0						
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (Wyoming residual) 50% (by volume)	25	do.	5.2	6.9	6.9	.497	100.0						

Table 2.--Condition of round longleaf pine experimental posts on the Harrison Experimental Forest, Saucier, Miss., after about 8-1/2 years of service. (Cont'd)

(All treatments by pressure impregnation. Posts were installed during April and May 1949.)

Preservative	Posts in test	Form of preservative	Retention of preservative: Minimum	Maximum	Average	Standard deviation	Condition of posts, December 1957: Serviceable	Removed because of: Decay	Decay, termites	Termites	Total removed	Average life[1]
	Number		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	Number	Percent	Yr.
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (Wyoming residual) 50% (by volume); fortified with 2-1/2% Pentachlorophenol (by weight of total solution)	25	...do....	5.3	6.7	6.0	.453	100.0						
Copper naphthenate, 0.5% copper-metal equivalent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do....	5.2	6.9	6.0	.540	100.0						
Gasco (oil-tar creosote)	25	...do....	5.1	6.8	5.9	.616	100.0						
Gasco (oil-tar creosote) with 2% pentachlorophenol (by weight)	25	...do....	5.3	6.8	5.8	.455	100.0						
Lignite coal-tar creosote	25	Oil	5.1	6.8	6.3	.518	100.0						
Lignite coal-tar creosote, 50% and coal-tar creosote (medium residue, low in tar acids and naphthalene), 50% (by volume)	25	Solution	5.6	6.9	6.3	.376	100.0						
Lignite coal-tar creosote, 50% and petroleum oil (Wyoming residual), 50% (by volume)	25	...do....	5.5	7.1	6.4	.440	96.0	4.0			1	4.0	
Pentachlorophenol:													
Five percent (by weight) in petroleum oil (No. 2 distillate)	25	...do....	5.1	7.0	6.3	.531	100.0						
Five percent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do....	5.3	7.0	5.9	.482	100.0						
Three percent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do....	5.3	6.9	6.0	.412	100.0						
Five percent (by weight) in petroleum oil (Wyoming residual)	25	...do....	4.5	7.4	6.0	.817	100.0						
Pentachlorophenol, 5% in petroleum oil (No. 4 aromatic residual), 50%; and copper naphthenate, 0.5% copper-metal equivalent, in petroleum oil (No. 4 aromatic residual), 50% (by volume)	25	...do....	5.4	7.0	6.2	.543	100.0						
Petroleum oil:													
Aromatic, high residue (S.W.)	25	Oil	5.1	6.7	6.1	.553	100.0						
Aromatic, low residue (S.W.)	25	...do....	5.1	6.9	6.1	.557	100.0						
Highly aromatic (S.O.)	25	...do....	5.1	6.9	6.0	.484	100.0						
Highly aromatic, high residue (S.O.)	25	...do....	5.1	6.9	6.1	.503	96.0	4.0			1	4.0	
No. 2 distillate (mid-United States)	25	...do....	5.0	7.2	5.9	.650	12.0	36.0	52.0		22	88.0	7
No. 4 aromatic residual (Calif.)	25	...do....	5.2	6.8	5.9	.448	96.0	4.0			1	4.0	
Wyoming residual	25	...do....	5.1	6.9	5.8	.691	36.0	52.0	12.0		16	64.0	8
Termitecl (softwood tar creosote)	25	...do....	4.9	6.9	6.1	.505	100.0						
Untreated control posts	25						20.0	80.0			25	100.0	2.3

[1]Average life taken from a mortality curve, except where all posts have been removed.

line installation was originally designed so that about 70 percent of the posts of each treatment were set on the drier, well-drained sites of the area (pine hills or dry hardwood sites), 20 percent in moist soil (pitcher-plant areas or any area with fluctuating water table), and 10 percent in swamp or standing water.[6] A careful check during several post inspections, which included both extremes of dry and wet weather, indicated that the segregation according to dry, damp, and wet sites varied slightly with the different treatments but was generally about 65 percent, 18 percent, and 17 percent, respectively.

In the line, 100 posts were originally installed for each preservative or treatment. The number of test posts has since been reduced for some treatments by fire loss and pilferage, or by other removals not occasioned by decay or termite attack.

The posts in the most recent installation on the Harrison Experimental Forest were set in a comparatively dry site during April and early May 1949. Twenty-five posts were installed for each treatment, along with 25 untreated control posts. These posts were installed in a plot by the randomized block method, by which the plot was divided into 25 blocks, each containing 1 post from each treatment and 1 untreated control post, selected at random. The posts were set 3 ft apart in rows, and the rows were 3 ft apart in the blocks.

The soil in the general area of Saucier, Miss., is reported to be a Norfolk fine sandy loam with a pH of 5.0 to 5.5. In the plot with the posts installed during 1949 the soil pH is 4.98 to 5.04.

Results to Date

During the December 1957 inspection, as in the previous inspections, each post was given a moderate push by the inspector, under the force of which it could usually be expected to break off if decay or termite attack had progressed to a critical point. If it did break off, the post was considered to have failed and the cause of the failure was determined.

Conditions of Posts Installed from 1936 to 1941

The conditions of the posts installed from 1936 to 1941 are shown in Table 1 and are discussed, according to preservatives and treatments used, in the following paragraphs.

Untreated control posts—The 65 untreated control posts set from late 1936 to February 1937 had an average life of 3.1 years, and the 33 installed during November and December 1938 had an average life of 3.7 years. The average life of all untreated posts in the line was 3.3 years. The untreated posts installed in well-drained, comparatively dry soil had an average life of 2.6 years and failed mostly because of decay and termite attack. Those installed in moist soil and in swamps or standing water had an average life of 4 and 4.8 years, respectively, and failed mostly because of decay. Some of the posts set in water remained serviceable for more than 5 years and failed mainly because of top decay. The untreated posts were removed as follows:

Years after installation	1	2	3	4	5	6
Number (cumulative) removed	3	33	60	79	93	98

Beta-naphthol, 5 percent in organic solvents—Approximately 94 percent of the posts treated with beta-naphthol solution have been removed. The estimated average life of the posts is 16 years on the basis of these removals. The average retention of

[6] Throughout the report these sites will be referred to as "dry," "damp," and "wet," although these terms are relative and apply only to the Mississippi test area.

preservative solution for the posts removed was 6.2 lb per cu ft, the same as that for the 100 posts originally installed. Removals have been due principally to combined decay and termite attack. Ninety-eight percent of the posts installed in dry sites, 100 percent of those installed in damp sites, and 72 percent of those installed in wet sites have been removed. Removals to date are as follows:

Years after installation	4	5	6	7	8	9	10	11	12
	13	14	15	16	17	18	19	20	21
Number (cumulative) removed	3	6	16	22	27	34	39	42	51
	55	65	71	79	83	87	89	91	92

Borax-boric acid—All posts treated with borax-boric acid have been removed after 20 years, and the average life of the 97 test posts is 10.6 years. Forty-six percent of the posts failed because of combined decay and termite attack, 36 percent because of termite attack, and 18 percent were removed because of decay alone. The 63 posts installed in dry areas had an average life of 9.8 years, while 17 posts in damp areas and 17 in wet areas had average lives of 11.0 years and 13.2 years, respectively. Removals by years are as follows:

Years after installation	5	6	7	8	9	10	11	12	13	14
	15	16	17	18	19	20				
Number (cumulative) removed	4	6	19	32	45	49	63	71	75	81
	87	90	91	93	94	97				

Celcure (acid copper chromate)—Celcure is prepared from copper sulfate and sodium dichromate in an acid solution. Approximately 17 percent of the posts treated with this preservative have been removed, mostly because of decay. The estimated average life of the 88 test posts is 30 years. The 15 posts removed had an average retention of 0.89 lb per cu ft; the average retention for the posts installed was 0.92 lb per cu ft. Twenty-three percent of the posts set in dry areas and 12 percent of those in wet sites have been removed. No failures have occurred in the damp sites. Removals to date are as follows:

Years after installation	1	3	4	5	9	12	16	19	20	21
Number (cumulative) removed	1	2	3	5	6	7	9	10	12	15

Chromated zinc chloride—Chromated zinc chloride contains not less than 77.5 percent of zinc chloride and 17.5 percent of sodium dichromate. Approximately 41 percent of the posts treated with this preservative have been removed because of decay or combined decay and termite attack. The estimated average life of the posts in test is 24 years. The average retention of preservative in the posts removed was 0.83 lb per cu ft, or slightly less than that for the installation. Sixty-two percent of the posts installed in damp sites have been removed; 37 percent and 33 percent, respectively, have been removed from the dry and wet sites. Removals to date are as follows:

Years after installation	4	5	6	7	9	10	11	12	14
	16	17	18	19	20	21			
Number (cumulative) removed	1	3	6	10	13	14	15	18	21
	25	30	32	35	37	39			

Coal tar—Twenty percent of the posts treated with coal tar have been removed because of decay or combined decay and termite attack. The estimated average life of the posts is 28 years. The average retention of coal tar in the 19 posts removed was 5.4 lb per cu ft, as compared with an average of 6.5 lb for the posts installed.

Of posts installed in the dry, damp, and wet areas, 2.5 percent, 13 percent, and 6 percent, respectively, have been removed. Removals to date are as follows:

Years after installation	5	7	9	11	13	14	15	16	17
	19	20	21						
Number (cumulative) removed	1	2	3	4	5	6	7	9	12
	14	16	19						

Coal-tar creosote—The coal-tar creosote used was of American Wood-Preservers' Association Grade 1. Ten posts treated with this preservative have failed because of decay. These posts had an average preservative retention of 5.3 lb per cu ft, compared with an average of 6 lb for the installation. The estimated average life of the posts is 32 years. Two removed posts were set in damp sites, one in a wet site, and seven in dry sites. Removals to date are as follows:

Years after installation	13	15	17	18	19	20	21
Number (cumulative) removed	1	2	3	4	5	7	10

Coal-tar creosote 50 percent and used crankcase oil 50 percent—Seven posts treated with an average of 4.3 lb per cu ft of a 50–50 solution of creosote and crankcase oil failed because of decay. These posts were removed from dry areas. Removals to date are as follows:

Years after installation	12	17	19	20
Number (cumulative) removed	1	5	6	7

Coal-tar creosote 10 percent and used crankcase oil 90 percent—Approximately 75 percent of the posts treated with a solution of 10 percent creosote and 90 percent crankcase oil have failed, principally because of decay. The estimated average life of the posts is 19 years. The 74 posts removed had an average solution retention of 5.3 lb per cu ft, as compared with an average of 7.1 lb for the original installation. Of all posts installed in dry, damp, and wet sites, 80 percent, 76 percent, and 53 percent respectively, have failed. Failures to date are as follows:

Years after installation	1	2	3	4	5	6	9	11	12
	13	14	15	16	17	18	21		
Number (cumulative) removed	13	31	37	48	50	55	57	61	63
	64	66	67	70	72	73	74		

Crankcase oil—Of the posts treated with automobile crankcase drainings, approximately 90 percent have been removed, mostly because of decay. The estimated average life of the 97 posts installed on this basis is 17 years. The average retention of oil in the removed posts was 7.6 lb per cu ft, the same as that for the installation. Ninety-five percent of the posts set in dry areas, 75 percent of those set in damp areas, and 81 percent of those set in wet sites have been removed. Failures to date are as follows:

Years after installation	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	16	17	18	20	21	
Number (cumulative) removed	7	31	42	45	52	54	58	60	64	65
	68	73	75	77	80	82	84	86	87	

Lignite coal-tar creosote—Approximately 39 percent of the posts treated with lignite coal-tar creosote have failed, principally because of decay or combined decay and termite attack. The estimated average life of the 97 posts in test is 24 years. The average retention of preservative for the 38 posts removed was 2.8 lb per cu ft, or considerably less than that of 6.3 lb for the posts installed. Forty-one percent of the posts installed

in dry areas have been removed; 35 percent have been removed from the damp and wet sites. Removals to date are as follows:

Years after installation	3	5	7	8	9	10	11	12	13
	14	15	16	17	18	19	20	21	
Number (cumulative) removed	1	2	3	7	8	10	11	14	18
	20	23	26	28	30	32	36	38	

Mercuric chloride—Thirty-eight percent of the posts treated by steeping in mercuric chloride have been removed, principally because of combined decay and termite attack or termite attack alone. The estimated average life for the 100 posts installed is 24 years. The preservative retention of the 38 posts removed was 0.11 lb per cu ft, or approximately the same as the average retention for the installation. Forty-three percent of the posts installed in dry sites have been removed; 35 percent and 22 percent, respectively, have been removed from the damp and wet sites. Removals to date are as follows:

Years after installation	8	9	10	11	12	13	14	15	16
	17	18	19	20	21				
Number (cumulative) removed	1	4	6	9	13	14	18	20	25
	28	30	31	36	38				

No-D-K (hardwood-tar creosote)—Sixty-two percent of the posts treated with No-D-K have been removed, mostly because of decay or combined decay and termite attack. The estimated average life of the 100 posts in test is 21 years. Seventy-eight percent of the posts set in dry areas, 37 percent of those set in damp areas, and 26 percent of those set in wet areas have been removed. The average retention of preservative for the posts removed was 5.6 lb per cubic foot, compared with 6.6 lb for the installation. Removals to date are as follows:

Years after installation	2	3	4	5	6	7	8	9	10	11
	12	13	14	15	16	17	18	19	20	21
Number (cumulative) removed	1	4	5	12	18	21	23	25	26	30
	31	33	36	37	48	54	55	58	59	62

Osmosar—The Osmosar preservative was reported to be a mixture of sodium fluoride, dinitrophenol, potassium dichromate, sodium arsenate, and gum arabic. Approximately 46 percent of the posts have been removed to date, mostly because of decay or combined decay and termite attack. The estimated average life of the 96 test posts is 23 years. Forty-five percent of the posts set in dry sites, 63 percent of those set in damp sites, and 33 percent of those set in wet sites have been removed. Removals to date are as follows:

Years after installation	5	6	7	10	12	13	14	15	16
	17	18	19	20	21				
Number (cumulative) removed	1	2	4	5	6	8	13	16	25
	27	33	35	40	44				

P.D.A. (phenyldichlorarsine) 0.84 percent (by weight) in gas oil—Approximately 61 percent of the posts treated with P.D.A. in gas oil have been removed, mostly because of combined decay and termite attack or termite attack alone. The estimated average life of the 94 posts in test is 21 years. The average retention of preservative solution in the 57 removed posts was 5.6 lb per cu ft, or slightly less than the average retention for the installation. Of the posts installed in the dry, damp, and wet areas, 73 percent,

56 percent, and 22 percent, respectively, have been removed. Removals to date are as follows:

Years after installation	5	6	7	8	9	10	11	12	13
	14	15	16	17	18	19	20	21	
Number (cumulative) removed	2	4	6	9	12	13	15	16	19
	28	30	36	41	46	50	55	57	

Pentachlorophenol, 4.82 percent (by weight) in used crankcase oil.—One post treated with this preservative was removed from a dry area after 17 years of service because of decay. This post was treated with 4.6 lb of solution per cubic foot.

Pentachlorophenol, 3.02 percent (by weight) in used crankcase oil.—Of the 92 posts treated wtih 3.02 percent of pentachlorophenol in used crankcase oil, 3 have been removed from dry sites because of decay. The average retention of preservative in these 3 posts was 4.1 lb per cu ft, which is lower than that of 6.4 lb for the posts installed. Removals to date are as follows:

Years after installation	8	13	19
Number (cumulative) removed	1	2	3

Sodium dichromate—Approximately 73 percent of the posts treated with sodium dichromate have been removed, for the most part because of termite attack or combined decay and termite attack. The average retention by the removed posts was 0.89 lb per cu ft, nearly the same as that for the installation. The estimated average life of the 97 test posts is 19 years. Seventy-five percent of the posts set on dry sites, 94 percent of those set on damp sites, and 50 percent of those set on wet sites have been removed. Removals to date are as follows:

Years after installation	5	7	8	9	10	11	12	13	14
	15	16	17	18	19	20	21		
Number (cumulative) removed	4	10	12	13	14	16	25	27	37
	40	50	55	61	64	68	71		

Sodium chromate—Seventy-five percent of the posts treated with sodium chromate have been removed, principally because of termite attack or combined decay and termite attack. The estimated average life of the 88 posts in test is 19 years. For the 66 posts removed, the average retention of sodium chromate was 0.97 lb per cu ft, or slightly greater than that of 0.93 lb for the installation. Eighty-five percent of the posts set in dry areas, 65 percent of those set in damp area, and 53 percent of those set in wet areas have been removed. Removals to date are as follows:

Years after installation	4	5	6	7	8	9	10	11	12
	13	14	15	16	18	19	20	21	
Number (cumulative) removed	1	9	10	13	21	23	25	33	37
	40	49	51	59	62	64	65	66	

Wolman salt (Tanalith)—Wolman salt (Tanalith) contains sodium chromate, sodium arsenate, sodium fluoride, and dinitrophenol. Approximately 35 percent of the posts treated with this preservative have been removed, mostly because of decay or combined decay and termite attack. The estimated average life of the 97 posts in test is 25 years. The 34 posts removed had an average preservative retention of 0.34 lb per cu ft or approximately the same as the average for the installation. Thirty-three percent, 41 percent, and 38 percent of the posts set on dry, damp, and wet sites, respectively, have been removed. Removals to date are as follows:

Years after installation	7	8	9	12	14	15	16	17	18	20	21
Number (cumulative) removed	2	3	4	6	10	13	19	21	29	32	34

Tetrachlorophenol, 2.9 percent (by weight) in used crankcase oil—Approximately 13 percent of the posts treated with 2.9 percent of tetrachlorophenol in used crankcase oil have failed because of decay. The estimated average life of the 92 posts in test is 31 years. The 12 posts removed had an average solution retention of 5.1 lb per cu ft; that for the installation was 7.1 lb. These removed posts constituted 18 percent of those installed in dry areas and 7 percent of those in damp sites. There have been no failures in the wet sites. Removals to date are as follows:

Years after installation	11	12	13	14	15	17	18	19	20
Number (cumulative) removed	1	2	3	4	5	6	9	10	12

Tetrachlorophenol, 4.83 percent (by weight) in used crankcase oil—Approximately 6 percent of the posts treated with 4.83 percent of tetrachlorophenol in used crankcase oil have failed in dry sites due mostly to decay after 21 years of service. The posts removed had an average solution retention of 5.4 lb per cu ft, compared with the average of 5.8 lb for the installation. Removals to date are as follows:

Years after installation	18	19	20	21
Number (cumulative) removed	2	3	4	6

Water-gas tar—Approximately 8 percent of the posts treated with water-gas tar have failed because of decay and combined decay and termite attack. One post failed in a damp site, and 6 failed in dry sites. The average retention of preservative in the 7 posts was 3.9 lb per cu ft, compared with the average of 6.3 lb per cu ft for the installation. Removals to date are as follows:

Years after installation	14	16	19	20	21
Number (cumulative) removed	1	2	4	6	7

Zinc chloride—Approximately 35 percent of the posts treated with zinc chloride, with an average retention of 0.99 lb per cu ft, have been removed because of decay or combined decay and termite attack. The estimated average life of the 96 posts in test is 25 years. Thirty percent, 56 percent, and 35 percent, respectively, of the posts set in dry, damp, and wet areas have been removed. Removals to date are as follows:

Years after installation	5	8	13	14	16	17	18	19	20	21
Number (cumulative) removed	1	2	3	9	15	18	23	25	32	34

Zinc meta arsenite—Zinc meta arsenite is prepared from arsenious acid, zinc oxide, and acetic acid. One post treated with 0.42 lb of this preservative per cubic foot was removed from a dry site after 20 years.

Copper sulfate and sodium arsenate applied by double diffusion—Two posts treated with copper sulfate and sodium arsenate applied by double diffusion have failed because of decay. One was located in a dry site and one in a wet site. Removals to date have been as follows:

Years after installation	12	16
Number (cumulative) removed	1	2

Osmoplastic (ground-line treatment)—The Osmoplastic used was reported to contain sodium fluoride, dinitrophenol, potassium dichromate, refined coal tar, and coal-tar

creosote. Approximately 95 percent of the posts treated with this preservative at the ground-line zone (a 15-in band extending 3 in above and 12 in below the ground line) and at the immediate tops have been removed after nearly 17 years of service. Removals were because of decay and termite attack, alone or in combination. The estimated average life of these posts is 13 years. Failures have occurred in 100 percent of the posts set in dry sites and in damp sites, and in 72 percent of those set in wet sites. Removals to date are as follows:

Years after installation	3	5	6	7	8	9	10	11	12	13	14	15	16
Number (cumulative) removed	1	3	6	13	19	23	39	54	68	74	82	85	95

Conditions of Posts Installed in 1949

All of the untreated control posts failed after approximately 3½ years of service. Their average life was 2.3 years. Failures were mostly because of combined decay and termite attack. Removals were as follows:

Years after installation	1½	2½	3½
Number (cumulative) removed	13	20	25

Forty-four treated posts failed because of decay and combined decay and termite attack after approximately 8½ years of service. Sixteen of the posts were treated with Wyoming residual petroleum oil, 22 with No. 2 fuel oil, 2 with aromatic petroleum oils, 2 with copperized chromated zinc chloride, 1 with Boliden salt A, and 1 with lignite coal-tar creosote, 50 percent and Wyoming residual petroleum oil, 50 percent. The estimated average life for posts treated with the No. 2 fuel oil is 7 years while that for the posts treated with Wyoming residual petroluem oil is 8 years.

Summation of Results

A summary of information obtained during the 21 years since the beginning of this study follows:

1. The untreated posts installed during 1937 and 1938 had an average life of 3.3 years. The untreated posts set in swamps failed mostly because of decay and lasted an average of 4.8 years. Those set in damp soil (outside of swamps) also failed mostly because of decay, after an average life of 4.0 years. Those set in well-drained, comparatively dry soil failed because of combined decay and termite attack after an average life of 2.6 years. The untreated control posts set in 1949 in a dry site had an average life of 2.3 years.

2. All of the posts treated with an average of 0.92 lb of borax-boric acid (50–50) per cubic foot failed after 20 years of service with an average life of 10.6 years. On the basis of removals to date and of the preservative retentions used, not including posts installed in 1949, posts given the following treatments are estimated to have an average life of 13 to 21 years: posts pressure treated with beta-naphthol in oil, 10 percent of coal-tar creosote and 90 percent of used crankcase oil, crankcase oil alone, No-D-K (hardwood-tar creosote), P.D.A. (phenyldichlorarsine), sodium dichromate, sodium chromate, and those treated at the ground line and top with Osmoplastic. Posts given the following treatments are estimated to have an average life of 23 to 32 years: posts pressure treated with Celcure (acid copper chromate), chromated zinc chloride, coal tar, coal-tar creosote, lignite coal-tar creosote, Wolman salt (Tanalith), tetrachlorophenol (approximately 3 percent) in used crankcase oil, and zinc chloride; posts steeped in

mercuric chloride; and posts treated full length with Osmosar. Posts pressure treated with 50 percent of coal-tar creosote and 50 percent of used crankcase oil, penta chlorophenol (approximately 5 percent and 3 percent) in used crankcase oil, tetra-chlorophenol (approximately 5 percent) in used crankcase oil, water-gas tar, and zinc meta arsenite, and those treated by the double-diffusion process with copper sulfate and sodium arsenate should last longer than 32 years on an average, but have not yet shown a sufficiently high percentage of removals to warrant an estimate on possible average life.

3. The failures of treated posts to date, on the basis of posts installed under the three site conditions, have been heavier in the dry and damp areas than in the swamps. In the installations showing more than 30 percent failure, the percentage of failures in the swamps has been significantly high.

4. The posts installed during 1940, except for petroleum oil-treated controls, have not been in test long enough to indicate important differences in the preservatives. Posts treated with No. 2 fuel oil and those treated with the Wyoming residual oil are estimated to have an average life of 7 years and 8 years respectively. One of the posts treated with Boliden salt A failed after 6½ years because of decay and 2 of the posts treated with copperized chromated zinc chloride failed within 5½ years because of decay caused by a fungus, *Poria ridiculosa,* which is fairly tolerant to copper compounds. In the case of posts installed in 1936 and treated with Celcure, another copper compound, a small percentage of the posts failed during the first years of test, presumably from decay caused by the same or a similar fungus. One post treated with 50–50 lignite coal-tar creosote and Wyoming residual petroleum oil failed after 7½ years, and 2 treated with different aromatic petroleums have failed during the same period.

Although some of the posts installed during 1936 and 1937 were pointed after treatment to facilitate driving in wet or damp sites (this practice should not be encouraged), few if any post failures can be charged to this factor alone. In most cases, the pointed part of the post was submerged in water or water-soaked soil so that decay and termite attack at the pointed section were not the controlling factors in its life. Furthermore, the posts were mostly of sapwood, which was generally well penetrated by the preservative, and cutting of such treated wood was less serious than it would be with poorly penetrated posts.

The results obtained in this particular test are not necessarily indicative of the performance that can be expected of the preservatives under other conditions of exposure. Furthermore, they should not be considered as indicating the service life to be expected from the preservatives applied to other species or applied by other methods. Water borne preservatives usually perform better under conditions not favorable to leaching than when used for the treatment of wood installed in contact with the ground or water. Some of the water borne preservatives appear to be performing well in this test, but the fact that others are performing less satisfactorily does not indicate that they will not provide adequate protection when used under drier or more favorable circumstances. Adequate retentions and penetrations are necessary for a high degree of protection with any preservative, and it follows that high retentions and heavy concentrations of preservative usually perform better than low retentions and low concentrations. For the preservatives included in Tables 1 and 2, Federal Specification TT-W-571 recommends the following minimum retentions for lumber and posts:

Preservative	Minimum Retention (Pounds per cubic foot) Lumber and structural timber: In contact with the ground or fresh water	Lumber and structural timber: Not in contact with the ground or water	Posts
Coal-tar creosote	10.0	6.0	6.0
Creosote petroleum solution (50–50)	12.0	7.0	7.0
Pentachlorophenol, 5 percent in petroleum	10.0	6.0	6.0
Copper naphthenate, 0.75 percent copper equivalent in petroleum	10.0	6.0	6.0
Acid copper chromate (Celcure)	0.75*	0.50	0.75
Ammoniacal copper arsenite (Chemonite)	0.50*	0.30	0.50
Chromated zinc arsenate (Boliden salt A)	1.00*	.50	1.00
Chromated zinc chloride	1.15*	.75	1.15
Copperized chromated zinc chloride	1.15*	.75	1.15
Osmosar (Osmosalts)	.55*	.35	.55
Tanalith (Wolman salts)	.55*	.35	.55

* Occasional exposure to water or constant exposure to the ground in areas of moderate rainfall.

Report on Assignment 8

Destruction by Marine Organisms: Methods of Prevention

A. P. Richards (chairman, subcommittee), W. Buehler, C. M. Burpee, G. L. Cain, R. F. Dreitzler, H. M. Harlow, B. D. Howe, M. F. Jaeger, P. B. Mayfield, F. H. Taylor, C. H. Wakefield.

This report, for period 1958–1959, is submitted by your committee in connection with the activities of destructive marine organisms and methods of preventing such deterioration.

PROGRESS REPORTS ON TEST PILES AND SPECIMENS

Through the cooperation of W. M. Jaekle, chief engineer of the Southern Pacific Company, the results of the latest inspections of the following test programs are given. The examination of the specimens was made by R. M. Alpen, manager of wood preserving plants for the Southern Pacific.

Report of the January 8, 1958, Inspection of Specimens Furnished by the Chemical Warfare Service and Placed on Test in San Francisco Bay at the Request of the Late Dr. Herman von Schrenk

Gate 25-1-A. Installed at Biological Station, Oakland Pier, July 1925, removed 1942, replaced 1946. The untreated pieces hung at this station, 1957, show heavy limnoria and heavy bankia attack, the average loss in weight being 30 percent.

No. 2. (Creosote and 1 percent diphenylamine chlorarsine). Heavy limnoria attack.

Chemical Warfare Service Test Pieces Forwarded from Edgewood Arsenal by Lt. Col. C. E. Brigham and Hung at Oakland Pier, February 1932, Removed 1942, Replaced 1946

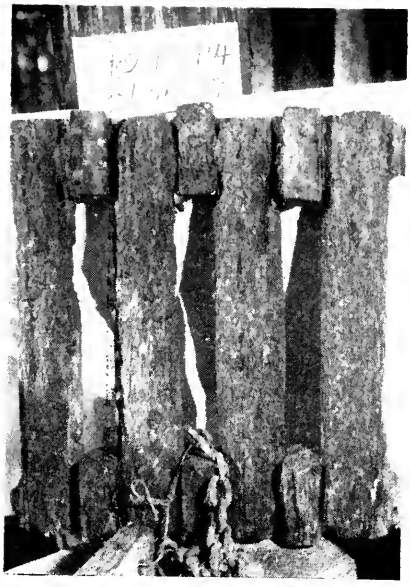
Specimen	Treatment	Condition
A–11	Creosote, 21.6 lb/cu/ft	Heavy limnoria attack
D–11	Creosote plus 2½% dinitrophenol 23, 7 lb/cu/ft	Heavy limnoria attack

Report of January 8, 1958, Inspection of Specimens Furnished Through Dr. H. von Schrenk and Col. Wm. G. Atwood and Installed in San Francisco Bay Area

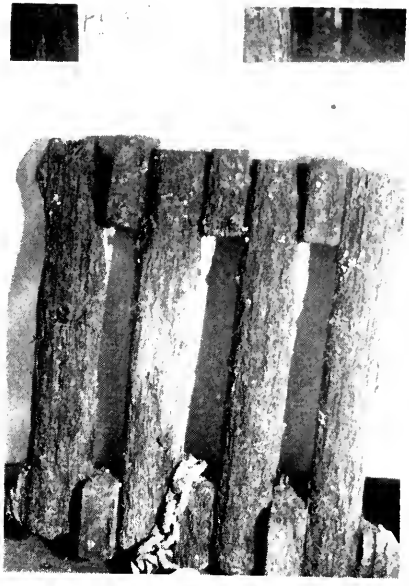
Barrett Manufacturing Company Material placed at Station B, Pier 7, San Francisco, January 1923, moved to Biological Station, Oakland Pier, SPCo., Dec. 1925, removed 1942, replaced 1946. Total exposure to date 30 years. (See accompanying photographs). (P—Pine; F—Fir)

Gate	*Specimen*	*Treatment*	*Condition*
B–4	P–1	Coke oven original	50% destroyed
	P–2	" " solids removed	Heavy limnoria attack
	P–3	" " acids removed	" " "
	P–4	" " bases removed	" " "
	P–5	" " oil minus residue at 360° C	Very heavy limnoria attack
	P–6	" " oil minus fraction 230–270	Heavy limnoria attack
	P–7	" " oil minus fraction up to 230	" " "
	P–8	" " oil minus fraction 270–360	" " "
B–6	P–9	Vertical retort original oil	Very heavy limnoria attack
	P–10	" minus solids	" " " "
	P–11	" " acids	50% destroyed
	P–12	" " bases	50% destroyed
B–7	P–13	" " residue above 360° C	Almost destroyed
	P–14	" " fraction 230–270° C	Very heavy limnoria attack
	P–15	" " fraction up to 230° C	Almost destroyed
	P–16	" " fraction 270–360° C	Destroyed
B–8	F–1	Same as P–1	Heavy limnoria attack
	F–2	" " P–2	Moderate limnoria attack
	F–3	" " P–3	Heavy limnoria attack
	F–4	" " P–4	Moderate limnoria attack
B–9	F–5	" " P–5	Heavy limnoria attack
	F–6	" " P–6	Almost destroyed
	F–7	" " P–7	Heavy limnoria attack
	F–8	" " P–8	" " "
B–10	F–9	" " P–9	" " "
	F–10	" " P–10	50% destroyed by limnoria
	F–11	" " P–11	Heavy limnoria attack
	F–12	" " P–12	" " "
B–11	F–13	" " P–13	Very heavy limnoria attack
	F–14	" " P–14	Heavy limnoria attack
	F–15	" " P–15	" " "
	F–16	" " P–16	" " "

The untreated specimens at this station, 1957, show heavy limnoria and heavy bankia attack; average loss in weight was 30 percent.



P–1, P–2, P–3, P–4



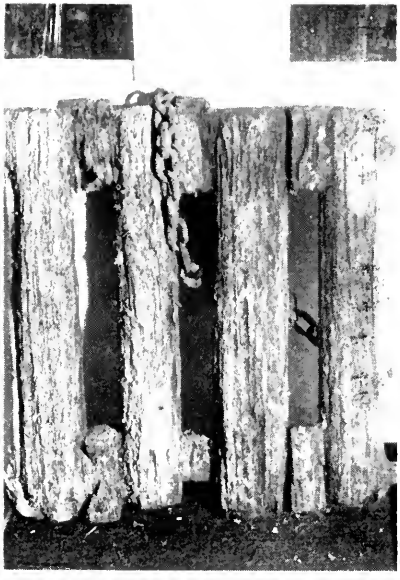
P–5, P–6, P–7, P–8

P–9, P–10, P–11, P–12

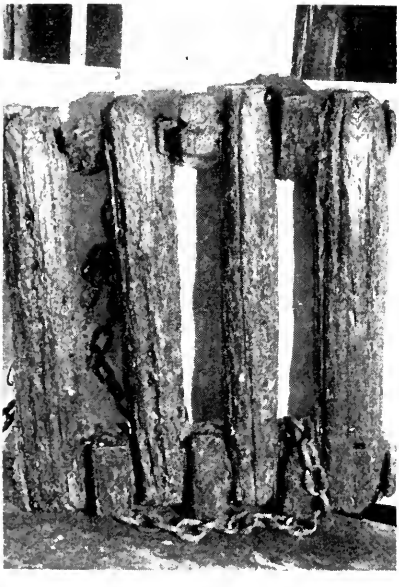
P–13, P–14, P–15, P–16

Pine specimens exposed in San Francisco Bay area.

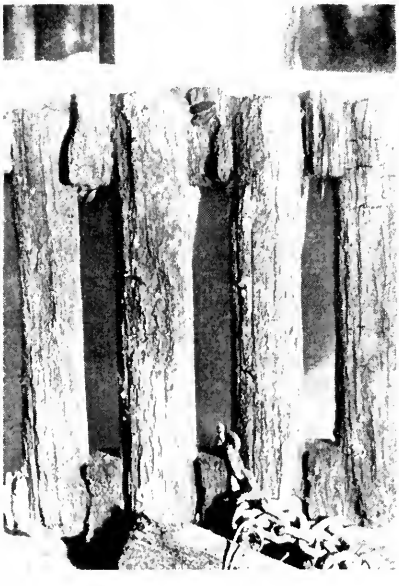
F–2, F–3, F–4, F–1



F–5, F–6, F–7, F–8



F–9, F–10, F–11, F–12



F–13, F–14, F–15, F–16

Fir specimens exposed in San Francisco Bay area.

Hercules Powder Company products exposed from 1948 to 1958 were found to be in the following condition:

Rosinamine D ..... Destroyed

Cuprolignum treated samples exposed from 1948 to 1958 were found to be in the following condition:

Cu_3, pressure treated ..... Heavy limnoria attack, about ½ destroyed
Copper naphthenate, pressure treated ..... Heavy localized limnoria attack

Four samples exposed April 5, 1950, to 1958 were as follows:

Standard (of Calif.) Wood Preservative
No. 1 6 lb/cu/ft ..... Destroyed by limnoria in 1954
No. 2 13.7 lb/cu/ft ..... Nearly destroyed by limnoria

Creosote
No. 1 12.6 lb/cu/ft ..... Moderate localized limnoria attack
No. 2 6.2 lb/cu/ft ..... Nearly destroyed by limnoria

Five samples treated with "Gasco" oils (Portland Gas & Coke Co.), exposed in October 1951, were reported to be as follows in 1958:

HC	Gasco creosote	14.6 lb/cu/ft	Light limnoria activity
LC	Gasco creosote	6.6 lb/cu/ft	Moderate limnoria activity
HD	Gasco distillate	13 lb/cu/ft	Light limnoria activity
MD	Gasco distillate	10.3 lb/cu/ft	Heavy limnoria activity
LD	Gasco distillate	3.9 lb/cu/ft	Heavy limnoria activity

Eight samples treated with various preservatives at West Oakland were exposed January 20, 1954. After 4 years exposure these were found to be in the following condition:

PCPL 4% pentachlorophenol in toxisol WTL, 12.85 lb/cu/ft ..... Destroyed
PCPH 10% pentachlorophenol in toxisol WTL, 12.85 lb/cu/ft ..... Destroyed

CL	Creosote	7.45 lb/cu/ft	Heavy localized limnoria attack
CM	"	10.58 lb/cu/ft	Nearly destroyed
CRM	"	18.97 lb/cu/ft	Light limnoria attack
CRL	"	13.24 lb/cu/ft	Heavy localized limnoria attack
CH	"	11.21 lb/cu/ft	Moderate limnoria attack

TEST BOARD STUDIES

The marine borer test panel studies at the William F. Clapp Laboratories, Inc., located in Duxbury, Mass., which have been in continuous operation for over 20 years, are being continued. By means of the monthly laboratory examination of untreated panels which have been submerged at approximately 300 locations on a nearly world-wide basis, long-range marine borer activity may be studied and evaluated from an engineering standpoint as well as for a basis of fundamental research. Annual reports dealing with these studies are published and may be obtained without charge from the Laboratories. Those sponsoring the work are the Navy Department, Bureau of Yards and Docks, as well as a number of private organizations.

WOOD PRESERVATIVE STUDIES

Work continues by numerous organizations regarding the search for new preservatives as well as the improvement of well known materials and treating techniques. During the past years considerable effort has been directed toward the development of an inspection method which would more accurately indicate the quality and location in the wood of the preservative used. Toward these ends there is now being proposed the "assay method" by means of which the amount of preservative present is referred to as the actual amount extracted from a given length of a standard diameter increment boring taken from the material after treatment.

Reference is made to the paper, "Determination of Retentions of Oil Preservatives in Heavily Treated Piling by the Extraction of Borings", by Dr. R. H. Baechler in the American Wood Preserver's Association, 1958, as well as to the Report of Preservative Committees of that same organization, in the 1955 proceedings for more detailed information regarding the apparatus used.

Present indications are that the method holds considerable promise.

Report of Committee 30—Impact and Bridge Stresses

D. S. Bechly, *Chairman,*
D. W. Musser,
Vice Chairman,

E. R. Andrlik
J. M. Bentham
E. S. Birkenwald
E. R. Bretschier
T. F. Creed, Jr.
J. W. Davidson
K. L. Deblois
W. E. Dowling
N. E. Ekrem
J. A. Erskine
A. T. Granger
A. R. Harris
R. H. Heinlen
W. B. Kuersteiner
C. V. Lund
J. F. Marsh
James Michalos
P. L. Montgomery
W. H. Munse
C. H. Newlin
N. M. Newmark
A. L. Piepmeier
M. J. Plumb
E. W. Prentiss
H. C. Prince
C. A. Roberts
M. B. Scott
J. H. Shieber
A. P. Smith
C. B. Smith
J. E. South
L. F. Spaine
F. W. Thompson
G. S. Vincent
J. R. Williams
W. M. Wilson (E)
J. D. Woodward
M. O. Woxland
L. T. Wyly

Committee

(E) Member Emeritus.

To the Amreican Railway Engineering Association:

Your committee reports on the following subjects:

1. Steel girder spans.

   Progress report, presented as information ..... page 380

2. Steel truss spans.

   No report.

3. Viaduct columns, collaborating with Committee 15.

   Progress report, presented as information ..... page 380

4. Longitudinal forces in bridge structures collaborating with Committees 7, 8 and 15.

   Progress report, presented as information ..... page 381

5. Distribution of live load in bridge floors:
   (a) Floors consisting of transverse beams.
   (b) Floors consisting of longitudinal beams.

   Progress report, presented as information ..... page 381

6. Concrete structures, collaborating with Committee 8.

   Progress report, presented as information ..... page 382

7. Timber structures, collaborating with Committee 7.

   Progress report, presented as information ..... page 382

8. Vibrational characteristics of bridges affecting deflections and depth ratios.

   Progress report, presented as information ..... page 383

9. Use of electronic computers for railroad bridge problems.

Progress report, presented as information ..... page 383

10. Steel continuous structures, collaborating with Committee 15.

Progress report, presented as information ..... page 384

11. Composite design of steel structures having concrete decks, collaborating with Committee 8 and 15.

No report.

THE COMMITTEE ON IMPACT AND BRIDGE STRESSES,
D. S. BECHLY, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 1

Steel Girder Spans

M. J. Plumb (chairman, subcommittee), E. R. Andrlik, D. S. Bechly, E. R. Bretscher, T. F. Creed, Jr., W. E. Dowling, H. C. Prince, C. A. Roberts, J. H. Shieber, A. P. Smith, C. B. Smith, L. T. Wyly.

A report on tests on three plate girder spans on the Genesee & Wyoming Railroad was published in Bulletin 544, as reported on under Assignment 3. This report covered the stresses in the girders and towers of a steel viaduct produced by diesel locomotives operating over the structure at a range of speeds up to 33 mph.

The research staff of the AAR is currently preparing information on the complete series of tests covering 37 steel girder spans for a summary report on this assignment.

Report on Assignment 3

Viaduct Columns

Collaborating with Committee 15

A. T. Granger (chairman, subcommittee), N. E. Ekrem, R. H. Heinlen, W. B. Kuersteiner, J. F. Marsh, C. H. Newlin, M. B. Scott.

A report on tests conducted in 1956 on a steel viaduct on the Genesee & Wyoming near Retsof, N. Y., was published in AREA Bulletin 544, June–July 1958, page 51. These tests were made at the expense and request of that railroad to determine the direct and bending stresses in certain members of the viaduct. Stresses were measured in the columns and tower bracing under static and dynamic loading to determine the effect of braking and traction forces.

Report on Assignment 4

Longitudinal Forces in Bridge Structures

Collaborating with Committees 7, 8 and 15

J. A. Erskine (chairman, subcommittee), J. M. Bentham, T. F. Creed, Jr., W. B. Kuersteiner, C. V. Lund, J. F. Marsh, A. L. Piepmeier, C. A. Roberts, L. F. Spaine, M. O. Woxland, L. T. Wyly.

A report on tests conducted on a steel viaduct on the Genesee & Wyoming Railroad was made under Assignment 3. This report includes the results of measurements of stresses produced in the tower bracing and in the rails by braking and accelerating the test train on the bridge.

A report on tests made on two ballasted-deck timber pile trestles on the Seaboard Air Line Railroad was published in Bulletin 545, as reported on under Assignment 7. Data on the effects of starting and stopping test trains on the bridge in producing longitudinal stresses in the running rails, bending in the piles, and pressure on the backwalls against the embankment are included in this report.

Report on Assignment 5

Distribution of Live Load in Bridge Floors

(a) Floors Consisting of Transverse Beams
(b) Floors Consisting of Longitudinal Beams

N. M. Newmark (chairman, subcommittee), D. S. Bechly, E. S. Birkenwald, J. W. Davidson, K. L. DeBlois, W. B. Kuersteiner, C. H. Newlin, E. W. Prentiss, J. E. South, M. O. Woxland.

An extensive study on this subject was started at the University of Illinois in 1957. During 1958 analytical methods were developed for studying the floor systems of bridges having either transverse floorbeams or longitudinal floorbeams. These methods of analysis will permit the study of the different variables in bridge floors which affect the floorbeam stresses. These variables include:

1. Number of floorbeams and their spacing.
2. Ratio of bridge length to bridge width.
3. Location of diaphragms and their stiffness.
4. Depth of ballast.
5. Train load.
6. Ratio of beam stiffness to slab stiffness (includes either steel plate or concrete slab).
7. Existence of composite action.

The analytical procedures are being correlated with bridge tests previously reported by Committee 30. With the aid of the University of Illinois digital computer, a large number of results will be obtained, including a complete range of each variable in the floor system.

After analysis of these results, simplification of the entire procedure will be made so that it will be readily useful in design office work. It is expected that this study will be completed in 1959.

Report on Assignment 6

Concrete Structures

Collaborating with Committee 8

P. L. Montgomery (chairman, subcommittee), J. W. Davidson, W. E. Dowling, N. E. Ekrem, J. A. Erskine, R. H. Heinlen, C. V. Lund, James Michalos, N. M. Newmark, A. L. Piepmeier, J. H. Shieber, A. P. Smith, F. W. Thompson, J. R. Williams, J. D. Woodward.

Initial work on the theoretical fatigue resistance of prestressed pretensioned concrete, and the satisfactory correlation between the theory and the laboratory testing of six beams subjected to static and repetitive loading, were done at Lehigh University in 1957. This work was reported in Bulletin 544, June–July 1958, page 1.

During 1958 the research staff of the Association of American Railroads conducted tests on two prestressed concrete bridges, one on the Santa Fe Railway at Colorado Springs, Colo., and the other on the Southern Railway at Dry Fork, Va.

The Santa Fe bridge is a single-track structure with two spans, 69 ft 10 in center to center of bearings. Each span has 4 post-tensioned girders with a cast-in-place concrete deck slab which forms the ballast trough and the sidewalks. The girders were designed for E 72 loading and full impact as prescribed in the current AREA specifications. A preliminary analysis of the records indicates a very uniform distribution of load between the four girders.

The Southern Railway bridge is a double-track structure in 3 spans, 26 ft 5½ in center to center of bearings. Each span has 12 rectangular pretionsioned beams. Precast concrete curbs are bolted to the outside beams to form a ballasted trough. The beams are not tied together laterally. They were designed for E 60 loading and full impact prescribed by the current AREA specifications. The records indicate that most of the live load is being carried by the four beams directly under the ties, which was an assumption made in the design. The report of the field test on these Southern Railway beams will be combined with data obtained during static testing of a similar beam by the research staff.

Report on Assignment 7

Timber Structures

Collaborating with Committee 7

C. V. Lund (chairman, subcommittee), E. R. Bretscher, T. F. Creed, Jr., K. L. DeBlois, R. H. Heinlen, C. H. Newlin, F. W. Thompson, J. R. Williams, J. D. Woodward, M. O. Woxland.

A report on tests on two ballasted-deck pile trestles located on the Seaboard Air Line Railroad appears in Bulletin 545, September–October 1958, page 143. This is the committee's first report on field tests undertaken specifically on timber trestles.

Analysis has been completed of tests made on four ballasted-deck pile trestles located on the Santa Fe, and a report is in preparation. In these tests strains were measured in the piling and stringers, and determination was made of braking and traction forces.

During the past year tests were conducted on a 60 ft long glued laminated girder

span located on the logging railroad of the Weyerhauser Timber Company near Longview, Wash. This is the first known test made of a girder span of this type under railroad loading. The data is currently being analyzed.

Report on Assignment 8

Vibrational Characteristics of Bridges Affecting Deflections and Depth Ratios

James Michalos (chairman, subcommittee), D. S. Bechly, K. L. DeBlois, A. R. Harris, M. J. Plumb, E. W. Prentiss, H. C. Prince, C. A. Roberts, M. B. Scott, J. E. South, G. S. Vincent.

An analytical study was started in the Department of Civil Engineering, New York University, in January 1957 to determine the effects of various parameters on the vibrational characteristics of railroad bridges. A method of analysis has been developed and programmed for solution by use of a digital computer; 95 percent of this programming has been completed.

Use of the computer will allow numerous studies to be made to ascertain the effects of such factors as depth ratio, stiffness, etc., on the dynamic behavior of bridges and rolling stock. Experimental records previously obtained by the research staff of the AAR are to be compared with the analytical results.

Report on Assignment 9

Use of Electronic Computers for Railroad Bridge Problems

E. R. Andrlik (chairman, subcommittee), D. S. Bechly, W. E. Dowling, J. Michalos, P. L. Montgomery, M. J. Plumb, E. W. Prentiss, H. C. Prince, L. F. Spaine, G. S. Vincent, J. R. Williams.

The use of electronic computers in the accounting departments of railroads has become common. A more recent application of these versatile machines is now being made in the field of engineering, where it has been found that their use will save valuable time in the solution of lengthy or repetitive problems. The computers have, in fact, made possible the solution of research problems that heretofore would have required prohibitive calculation time.

A major deterrent to the use of the computer in an engineering application is the time required to develop the machine program for a given problem. One railroad, working alone, may not have enough similar problems to warrant the expense of writing a program for their solution. The large group of railroads represented in the AREA, however, affords an opportunity to spread the cost of developing programs for common problems over a far wider base.

A railroad bridge problem common to all railroads, and one that with present methods requires a vast number of technical man-hours for solution, is the comparative rating of bridges and moving loads, coupled with the stress analysis of truss bridges. As part of this assignment, your committee proposes to develop computer programs for the solution of these problems. When developed, these programs will be made available to the individual railroads for their use, or if any road does not have the necessary computer available, its problems may be referred to the Research Center

of the AAR for solution. Another proposed service is the development and distribution of shear and moment tables for the many large, high-capacity freight cars now in operation in this country.

Because of the shortage of necessary personnel on the Research Center staff, it was felt necessary to contract for the development of these programs, in order to make them available at the earliest possible date. Accordingly, Hazelet and Erdal, consulting engineers in Chicago, have been engaged to do this work. The programs are being developed for the IBM Model 650 computer, which appears to be the computer most commonly in use.

The programming for the development of shear and moment tables for any given combination of wheel loads is nearly completed, and it should be available for distribution early in 1959. The program for the analysis of truss bridge stresses under dead load and live load is being developed concurrently, and its solution is expected to follow later next year. The basic truss program is being written to cover simple truss spans of symmetrical construction having parallel or non-parallel chords, any number of panels, and with or without counters. Expansion of this program to cover other cases is planned for the next stage of this assignment.

Report on Assignment 10

Steel Continuous Structures

Collaborating with Committee 15

A. R. Harris (chairman, subcommittee), E. R. Andrlik, J. M. Bentham, E. S. Birkenwald, J. W. Davidson, A. T. Granger, J. F. Marsh, W. H. Munse, D. W. Musser, H. C. Prince, C. B. Smith.

During 1957 field tests were made of three bridges with continuous steel spans on the heavy freight and passenger traffic main line of the Southern Pacific Company near Redding, Calif. The principal purpose in making tests on these continuous spans was to determine their dynamic behavior and the shape of the moment curve as compared to simple spans. These tests are outlined as follows:

1. Bridge No. 283.77, three 192-ft 6-in deck riveted truss spans with timber ballasted floor, E 72 design, over Doney Creek. The superstructure is fixed to one abutment with a horizontal traction anchor, and the other bearings are expansion rockers. Runs were made from 5 to 60 mph with (a) a test train covering one span, and (b) a test train covering two spans, so that the maximum moment diagram could be constructed. Readings were also taken to obtain secondary stresses.

2. Bridge No. 282.93, three 40-ft deck plate-girder spans with concrete-slab ballasted deck, E 72 design, on a 3-deg curve. The two piers are steel bents on rock foundation. The distribution of stresses between the top and bottom flanges was obtained to determine the composite action effect of the concrete deck.

3. Bridge No. 284.16, two 46-ft 8-in through plate-girder spans with transverse floorbeams and concrete ballasted deck, E 72 design, on spiral run-off from 2 deg curve, over U. S. Highway No. 99. The center pier is a steel bent on rock foundation.

The data obtained in these tests have been analyzed by the research staff of the AAR, and will be reviewed by Committee 30 during 1959.

Report of Committee 22—Economics of Railway Labor

L. A. Loggins, *Chairman,*
J. E. Eisemann,
Vice Chairman,
L. C. Gilbert, *Secretary,*
Lem Adams (E)
A. D. Alderson
M. B. Allen
R. M. Bailey
V. A. Barnhart, Jr.
J. F. Beaver
W. H. Brameld (E)
E. J. Brown
R. H. Carpenter
A. B. Chaney
W. E. Chapman
B. S. Converse
S. A. Cooper
P. A. Cosgrove
C. G. Davis
L. R. Deavers
L. E. Donovan
M. H. Dick
W. M. S. Dunn
H. J. Fast
J. L. Fergus
R. T. Fortin
R. L. Fox
R. J. Gammie
R. A. Gravelle
V. C. Hanna
E. B. Harris
Gene L. Harris
W. W. Hay
W. H. Hoar
R. J. Hollingsworth
T. B. Hutcheson
Claude Johnston
H. W. Kellogg
N. M. Kelly
H. E. Kirby
R. L. Mays
J. S. McBride (E)
J. R. Miller
H. C. Minteer
G. M. O'Rourke
R. W. Pember
C. T. Popma
R. R. Pregnall, Jr.
R. W. Preisendefer
M. S. Reid
D. E. Rudisill
H. W. Seeley, Jr.
E. J. Sierleja
R. G. Simmons
J. S. Snyder
F. R. Spofford
John Stang
A. H. Stimson
J. T. Sullivan
W. B. Throckmorton
W. H. Vance (E)*
H. J. Weccheider
H. M. Williamson
H. E. Wilson
F. R. Woolford
C. R. Wright

Committee

(E) Member Emeritus.
* Died February 11, 1958.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.

   Progress report, presented as information ..... page 387

3. Labor economies to be derived from cyclic maintenance.

   Final report, presented as information ..... page 402

4. Relative advantages of renewing ties in advance of out-of-face surfacing with mechanized tie gang, compared with renewing ties with a surfacing gang.

   Report presented as information, with recommendation subject be discontinued ..... page 404

5. Labor economies to be effected through use of power tools and mechanized equipment by bridge and building gangs.

   Progress report presented as information ..... page 407

6. Labor economies to be derived from the use of radio by maintenance of way gangs.
Progress report presented as information, with recommendation that subject be discontinued for several years and then renewed ..... page 411

7. The specific and ultimate improvements in various types of track maintenance equipment that would provide the greatest economies in maintenance practices and how these potential economies would compare with present costs, collaborating with Committee 27.
Progress report, submitted as information ..... page 411

8. Labor economies to be derived from the use of various machines available for calculating and for lining curves.
Final report, submitted as information ..... page 413

9. Relation between the nature of traffic and the interval between out-of-face resurfacing of tracks of relatively similar characteristics.
Progress report presented as information ..... page 416

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR,
L. A. LOGGINS, *Chairman.*

AREA Bulletin 547, December 1958.

MEMOIR

William Herbert Vance

A man who was symbolic of all the loyal, conscientious and hard-working members of the American Railway Engineering Association passed away at his home in Louisville, Ky., on February 11, 1958. He was William Herbert Vance, who retired in 1947 as assistant engineer maintenance of way of the Missouri Pacific Railroad.

Mr. Vance joined the AREA in 1911, and became a Life Member of the Association in 1946. His longest term of AREA service was with Committee 22—Economics of Railway Labor, of which he was a member for 21 years. In 1953 he was made a Member Emeritus of that committee, and thus continued to serve until his demise.

Mr. Vance was born in Effingham, Ill., on November 6, 1876, the son of John Albert Vance and Nancy Ellen Barnsback Vance. In 1902 he was married to Julia Tindall, who died in 1955. They are survived by one daughter, Mrs. Nancy Ruth Baldwin.

Prior to his graduation from the University of Illinois in 1899 (B.S.C.E.), Mr. Vance spent several summer vacations on various field engineering jobs. Following his graduation he was engaged for three years in river surveys, channel improvement, and maintenance and operation of locks, all under the War Department, United States Army.

Mr. Vance's railroad career began in 1902 and spanned a period of 45 years until his retirement in 1947. During all of this period he was engaged in railroad construction, engineering and maintenance. First with the Peoria & Eastern in subordinate jobs for three years, he gained valuable experience in work involving replacement of wooden bridges and trestles with steel and concrete structures, construction of yards and related facilities, and in track relocation and maintenance. Then followed a 14-month period as assistant engineer on the St. Louis, Iron Mountain & Southern, which was notable for the maintenance experience he acquired.

On June 1, 1906, Mr. Vance was appointed division engineer on the Louisiana & Arkansas. He remained with that company nearly 11 years, becoming progressively engineer maintenance of way and chief engineer, with attendant responsibilities. Following a 15-month period of service as engineer maintenance of way of the St. Louis Southwestern Lines, which began on April 1, 1917, he served under the United States Railroad Administration until March 1, 1920, as top maintenance officer of the St. Louis Southwestern and associated area properties.

Mr. Vance's career with the Missouri Pacific began on March 1, 1920, and extended over a period of more than 27 years until his retirement on August 31, 1947. He joined that property as district engineer of its Southern District, and retired as assistant engineer maintenance of way, System. In the interim he was a most loyal and conscientious officer and an able administrator widely recognized for his sound professional judgment, for which his thorough and well-rounded experience so well fitted him.

In addition to his 26 years of service with AREA Committee 22, Mr. Vance was for two years (1918–1920) a member of Committee 7—Wood Bridges and Trestles, and also, in 1936–1938, a member of Committee 12—Rules and Organization. It was for Committee 22, however, that his most notable work was performed. His chairmanship of several of its subcommittees was outstanding, and his active participation in all of the deliberations of the committee was marked by his forward-thinking and serious purpose. He contributed unstintingly of his experience, knowledge and time. Among others, many of the younger members were indebted to him for sound advice and counsel.

A man with few outside interests or hobbies, Mr. Vance was chiefly concerned with his family and home, his church and his profession.

In addition to being a Life Member of the AREA, Mr. Vance was a life member of the American Society of Civil Engineers, and was active in the American Railway Bridge and Building Association. He was a registered civil engineer for 45 years.

L. A. Loggins,
J. S. McBride,
A. B. Chaney,
H. E. Kirby,
Committee on Memoir.

Report on Assignment 2

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

J. S. Snyder (chairman, subcommittee), M. B. Allen, V. A. Barnhart, Jr., J. F. Beaver, E. J. Brown, R. H. Carpenter, B. S. Converse, S. A. Cooper, L. E. Donovan, J. E. Eisemann, J. L. Fergus, V. C. Hanna, W. W. Hay, R. J. Hollingsworth, T. B. Hutcheson, Claude Johnston, H. W. Kellogg, H. E. Kirby, H. C. Minteer, G. M. O'Rourke, R. W. Prisendefer, M. S. Reid.

This report is submitted as information.

Your committee is making the seventeenth report of a series on this subject which has been reassigned annually since 1935. The current study covers the program in effect on the Missouri Pacific Railroad to reduce its cost of maintaining trestle bridges and highway crossings, and installing ties. The committee and guests were provided an excel-

lent and profitable opportunity to inspect the property of the Missouri Pacific Railroad at Little Rock, Ark. This included the concrete products yard, the timber framing plant, a concrete pile trestle of recent construction, a recently installed heavy-duty road crossing, the operation of a tie gang and the operation of a specially fitted gondola car for the distribution of ties.

Concrete Products Yard

Approximately 30 years ago, the Missouri Pacific adopted a plan to replace the timber trestles on its primary lines with pre-cast concrete pile and concrete-slab bridge construction. The work is being programmed with company forces doing the preponderance of the work, and a concrete products plant was established at Benton, Ark., and later moved to the present site in Little Rock.

This plant is operated by the bridge engineer as a fabricating plant for 14 road system bridge gangs under his direct supervision on the three districts of the Missouri Pacific. Nine of these gangs are 20-man concrete trestle gangs, one is a 20-man structural steel erection gang and 4 gangs have 10 men each for steel bridge repairs. The fifteenth gang of 29 men operates the concrete products plant at Little Rock.

In addition to producing all the concrete piles and concrete slabs used on the Missouri Pacific, this plant also produces standard concrete backwall members and signal foundations. It is equipped to cut and bend the reinforcing steel, as required, and fabricate miscellaneous structural steel items, such as grillages and minor replacement members.

Initially, the trestle bents were constructed of 16-in octagonal concrete piles, using 5 piles for each bent. This plan involved considerable work shifting the timber deck to permit driving the new piles. Later the design was changed to use three 24-in octagonal concrete piles per bent. A few 16-in concrete piles are still used where close clearances are involved and for foundation piling.

The plant consists of a reinforcing steel storage yard and a steel tying area equipped with necessary jigs and a power bender for reinforcing steel. This equipment is designed to simplify tying and forming the reinforcing steel mats before they are placed in the forms. All the steel mats for the concrete piles and the bridge slabs are assembled and tied in this area and later placed in the forms by a locomotive crane.

Adjacent to the steel tying area, there is a reinforced concrete casting table (45 by 210 ft) for casting concrete piles. Ramps are provided at each end of the table for ready-mix concrete trucks. Concrete is delivered from the truck to the forms by concrete buggies. It is now proposed to rearrange the ramps in order that the concrete can be delivered directly from the truck to the forms. The plant produces 16-in and 24-in concrete piles from 20 to 55 ft in length. Normally, 7 piles per day are poured; the piles are stripped the second day and the steel forms are set up in the adjacent area, whereupon, the operation is repeated. The 24-in piles weigh approximately 500 lb per ft and are removed from the casting table by a locomotive crane 72 hr after pouring. They are placed in a large storage area south of the plant.

The concrete piles are stocked according to the best estimated requirements for the anticipated program of bridges for renewal, and at present, approximately 400 piles are in stock. The normal practice in providing piles for a new project is to ship two cars to the job site containing piles of the estimated required length. Test piles are driven at several bents, and subsequent shipments are scheduled in proportion to driving progress. Thus, penetration changes can be adjusted without field splices or excessive cutoffs. Where ground collars are involved, a recent practice is to use precast posts spliced into the collar of the pile, utilizing posts and shorter piles at less unit cost

per foot over longer piles. Immediately west of the pile table are two small tables where concrete backwall segments are cast.

Across the crane runway track and opposite the pile casting table is the concrete slab table. This table is 321 ft long and 16 ft wide and permits pouring two panels of standard concrete slabs per day. The forms used on bridge slabs are steel and of a very simple design that can readily be adapted to various length panels. Skew ended or haunch slabs require special form work and cannot be produced on a production basis. The slab production works from both ends of the table, and when the center forms are filled, the end slabs are five days old and can be removed from the table and the operation repeated. The slabs are not placed in service until 21 days old and are identified by panel number, bridge number and date cast. Bridge slabs vary in length from 16 to 24 ft and weigh approximately 1 ton per lin ft. Service roads located on each side of the slab table permit the ready-mix trucks to pour concrete from the trucks directly into the slab forms.

Adjacent to the bridge slab table and south of it there is a small table where signal foundations are cast, utilizing any surplus concrete left after the bridge slabs are poured. Again, steel forms are used to simplify the manufacture of these units.

The committee had an opportunity to inspect a flat car equipped as a mixer car used by the foundation gangs at bridge sites where ready-mix concrete is not available. This is equipped with a ½ cu yd mixer, water storage tank, steel aggregate bins and a bucket conveyor that provides much better concrete with very little labor required to charge the mixer. The car is designed to pour 25 cu yd of concrete without refilling. The equipment repair shop and equipment storage shed was inspected. All construction equipment for the system bridge gangs except cranes and motor cars is scheduled for periodic overhaul at this location, and costly delays due to equipment failures are reduced to a minimum.

Metallizing Structural Steel Members

The committee observed a wide-flange beam span being treated to protect the top flanges against brine damage. The top surfaces and edges of the top flanges in all new deck-girder spans and the corresponding surfaces of stringers and floorbeams in new truss spans are coated with a mechanical bond of molten zinc to an average thickness of 0.012 in prior to erection. In some instances, the top flanges of girders and floor members deteriorated by brine drippings have been repaired by a combination of welded cover plates and metallizing at considerable less cost than replacement.

The surface to be metallized is first sand blasted with a coarse chatt sand to provide a rough surface and then molten zinc is sprayed by means of a gun. The production of this process has been greatly increased by guns designed for $\frac{3}{16}$-in wire and mechanical sand driers. Traffic conditions control to a great extent the cost of such work on bridges in service. Damp days and extreme cold weather prevent successful metallizing.

Concrete Trestle Bridge

The concrete trestle approach to Little Rock Junction Bridge No. 3452 was inspected by the committee. This bridge is a typical example of the type of work the Missouri Pacific has programmed to reduce its maintenance on wooden trestles.

The concrete trestle of 11 panels and a total length of 208 ft was constructed in 1945–1946 and replaced a 17-panel untreated pile trestle bridge and one I-beam span over a highway—a total length of 215 ft.

The following is a table of quantities and cost data:

Quantities

35—24-in reinforced concrete piles (1,656 lin ft)
100 cu yd reinforced concrete (caps, abutments, sidewalks)
12,800 lb reinforcing steel
21 reinforced concrete slabs
2,742 lb pipe handrail
110 cu yd rock ballast
132 cross ties

Actual Cost (labor and material)

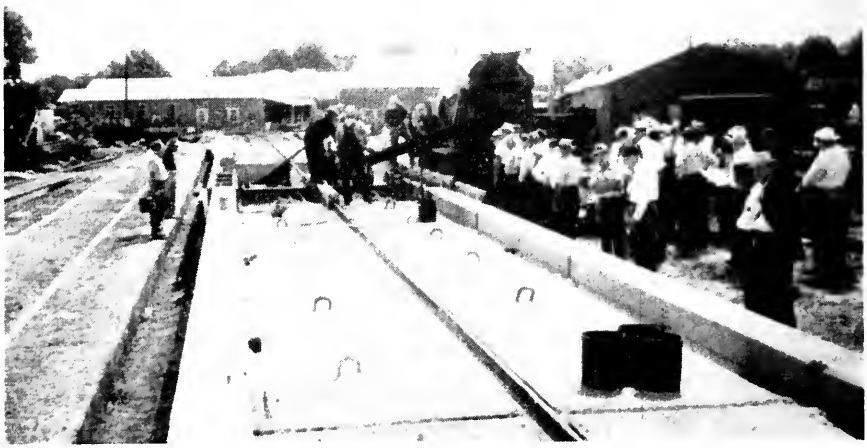
R & E	$17,007	
Operation	4,758	
Total	$21,756	($105 per lin ft)

Estimated Cost (labor and material—based on 1958 wages and prices)

R & E	$32,418	
Operation	5,682	
Total	$38,100	($183 per lin ft)

Bridge 3452 was built in 1946 at a cost of $105 per track ft. At present the cost would amount to $183 per track ft. The latter cost is representative of average current costs at present production levels. Traffic conditions, pile lengths, flood conditions and, particularly, locomotive-crane performance exert considerable influence on cost figures. Curtailed production in this program may also increase costs which will be difficult to offset by improved methods or new equipment.

(Text continued on page 394)



Pouring concrete bridge slab.

Manufacturing Costs of Concrete Piles and Slabs—January Through May 1958

1. 24-In Concrete Piles

Length, feet	20	25	30	35	40	44½	50	55
Labor per ft	$0.79	$0.79	$0.79	$0.79	$0.79	$0.79	$0.79	$0.79
Material per ft	1.76	1.87	2.16	2.51	3.17	3.34	4.03	4.10
Total per ft	$2.55	$2.66	$2.95	$3.30	$3.96	$4.13	$4.82	$4.89

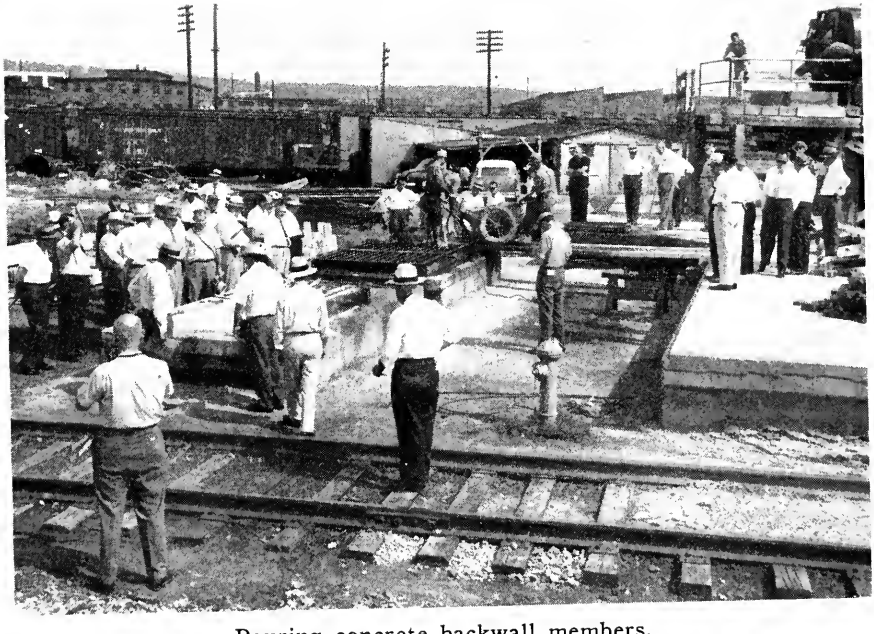
2. Concrete Track Slabs

Length, feet	15	16	17	18	19	20	21	22	23	24
Labor per slab	$ 37.89	$ 40.46	$ 43.13	$ 45.91	$ 48.32	$ 50.68	$ 53.05	$ 55.42	$ 58.73	$ 61.10
Material per slab	148.11	165.54	179.87	201.09	213.68	243.32	263.95	301.58	335.27	371.90
Total cost	$186.00	$206.00	$223.00	$247.00	$262.00	$294.00	$317.00	$357.00	$394.00	$436.00

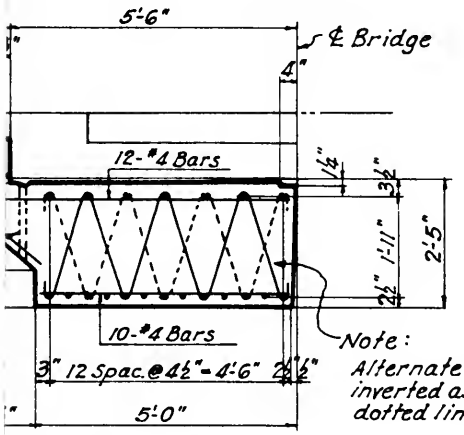
Total Production of Piles and Slabs 1932 through 1957 (25 years)

24,698—24-in concrete piles (841,240 lin ft, average length 38.8 ft)
6,520 Concrete track slabs (various sizes)

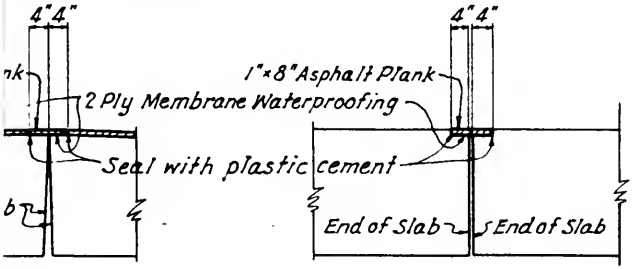
Pouring 24-in concrete piles.



Pouring concrete backwall members.



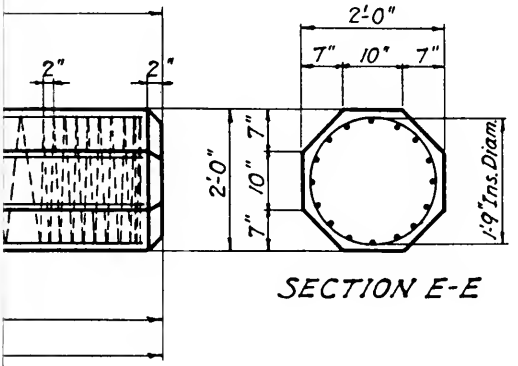
SECTION B-B



C-C SECTION D-D

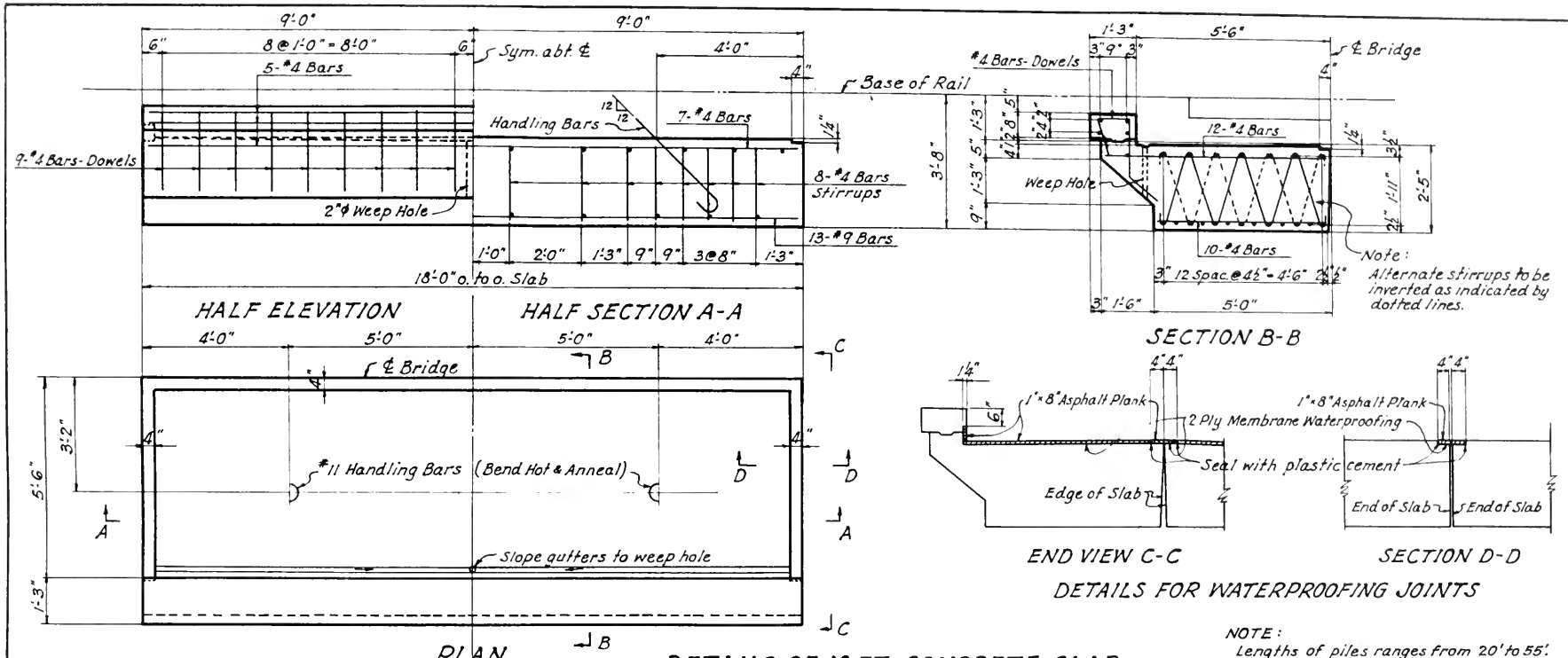
S FOR WATERPROOFING JOINTS

NOTE:
Lengths of piles ranges from 20' to 55'.
Lengths of slabs ranges from 16' to 24'.
Cross section of slabs is same for all lengths.



SECTION E-E

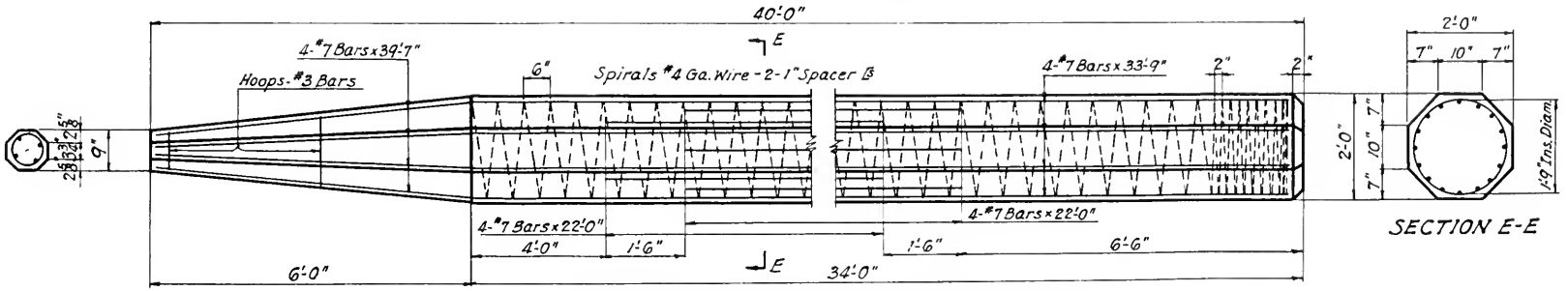
MISSOURI PACIFIC R.R.
TYPICAL CONCRETE SLAB & PILE



DETAILS OF 18 FT. CONCRETE SLAB

Scale ⅜" = 1'

NOTE:
Lengths of piles ranges from 20' to 55'.
Lengths of slabs ranges from 16' to 24'.
Cross section of slabs is same for all lengths.

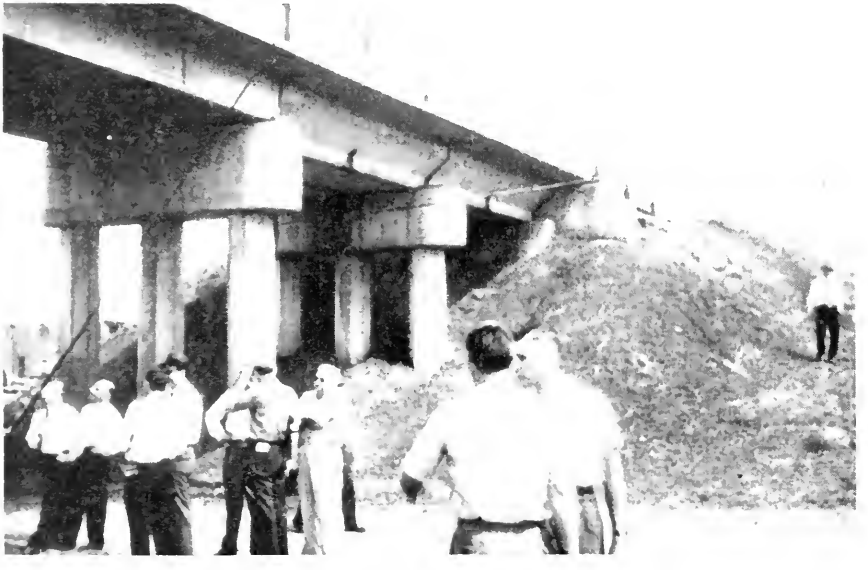


DETAILS OF 24" x 40 FT. CONCRETE PILE

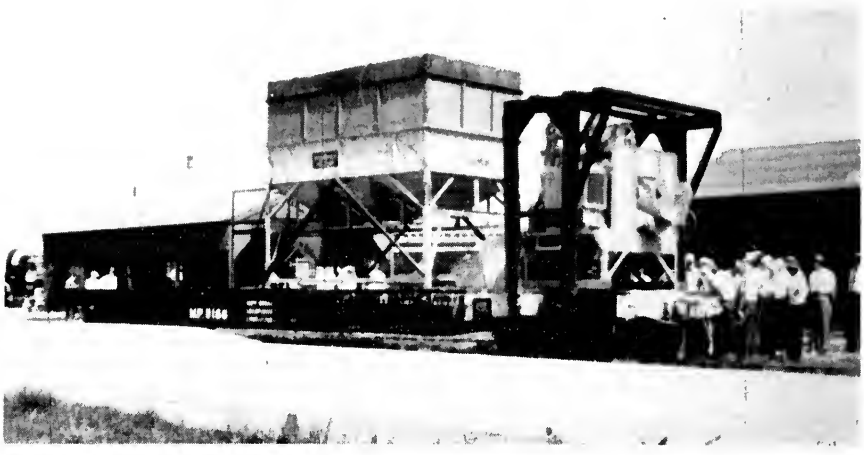
Scale ½" = 1'

MISSOURI PACIFIC R.R.
TYPICAL CONCRETE SLAB & PILE

Metallizing top flange of steel beam span.



Concrete trestle approach to bridge No. 3452.



Concrete mixer car.

Special Tie Cars

In 1955, tests with five special tie cars demonstrated the economy in their use for handling ties from treating plants.

In 1956, 115 additional cars were authorized, which cost $161,005, or $1400 per car, as follows:

$ 330—Salvage value of retired gondola car
1,070—Labor and material converting to tie car

$1,400—Total

The 115 cars are numbered TX–1885 to TX–1999.

Principal advantages of the special tie cars are:

1. Reduce hazard of personal injuries.
2. Reduce unloading costs to 5 to 6 cents per tie.
3. Release other cars for revenue service.

Timber Preframing Mill

The Missouri Pacific has been preframing bridge timbers and bridge ties before treating for the past 35 years; however, with the program in effect to replace timber trestles with concrete pile trestles, the need for preframing bridge timber has been reduced considerably. In 1955 the preframing mill was enlarged to accommodate the manufacture of full-depth plank highway crossing units. The plant is operated by a unit of the division bridge and building gang and consists of an assistant foreman, five mechanics and seven helpers. The gang works under the supervision of the Arkansas Division bridge and building supervisor, collaborating with the treating plant supervisor.

Solid timber highway crossing units are fabricated to specifications shown on the standard plan as requisitioned for a particular crossing location. A sketch plan accom-

Cost of Unloading Cross Ties from Special Tie Cars, Using Work and Way Freight Train Service

Division	Number		Number of M of W Man-Hours				Costs—Labor			
	Ties	Cars	Unloading	Train Delays	Travel Time	Total	M W Labor	Train Crew	Total	Per Tie
Eastern	3,336	9	36	9	9	54	$101.94	$113.00	$ 214.94	$0.065
Missouri	2,408	6	39		13	52	98.90	61.80	160.70	0.067
Louisiana	5,223	13	97	15	8	120	224.70	75.30	300.00	0.057
Arkansas	7,253	18	107	26	18	151	262.38	191.15	453.53	0.062
Total	18,220	46	279	50	48	377	$687.92	$441.25	$1,129.17	$0.062

Notes: Includes time for foremen.
Average unloading density—310 ties per mile.
Average cost per tie—M of W labor $0.0378
Average cost per tie—Work train crews $0.0242
Compiled from 1958 reports (January to May)

panies each requisition and gives all pertinent information concerning the weight of rail, angle of intersection of highway and railroad, and the width of highway.

The committee inspected the timber preframing mill and observed the manufacture of the solid timber plank crossings.

The preframing plant is located at the tie yard and the following equipment is used:

Saw Mill—48-in circular saw powered by a 440-v 50-hp electric motor.

Planer Mill—The planer is run by two 440-v 50-hp electric motors. It will plane a 24 by 30-in piece of timber.

Cut-off Saw—The 36-in circular saw is powered by an 1800 rpm, 220-v, 10 hp electric motor and is overhead suspended.

Angle Saw—Same as above.

Dado Saw—The 16-in circular saw, powered by a 220-v, 7½-hp electric motor, is overhead suspended.

Multi-Borer—The 10-spindled multiborer is powered by a 220-v, 10-hp electric motor and the carriage is operated by a 220-v, 3-hp electric motor.

Dust-Control System—Running from all this equipment are duct works that carry sawdust from the machines to the blower house and from the blower house to the incinerator. The exhaust system is operated by two 42-ft fans, one fan powered by a 10-hp electric motor and the other fan by a 220-v, 20-hp electric motor.

Investment in Timber Preframing Plant at North Little Rock, Ark.

Description	*Buildings*	*Machinery*	*Total*
Saw Mill (1947)			
Shed	$ 595	$ 2,323	$ 2,918
Sizer House (1953)			
Sizer House	1,766	8,085	9,851
Blower House	455	977	1,432
Blow Pipe System		3,284	3,284
Incinerator	5,492		5,492
Platforms	661		661
Miscellaneous	440		440
	$ 8,814	$12,346	$21,160
Crossing Plant (1957)			
Metal Building and Multi-Borer	3,477	27,833	31,310
Total Investment	$12,886	$42,502	$55,388

The full-depth plank highway crossings are made from cross ties purchased by the tie and timber department at on-line locations and shipped to the North Little Rock tie yard. The ties are placed in the storage yard in the proper stacks for seasoning.

When the cross ties are properly seasoned, fork lift trucks move the ties from the storage yard to the loading dock at the saw mill. The ties are sized and placed on a conveyor and moved to the planing mill. After planing, the material is stacked on a loading dock. These two operations are continuous until all material has passed.

The material is again placed on the conveyor and passed to the cut-off saw and

cut to the desired length; then passed to the multi-drill; then to the dado saw where the timbers that fit each side of the rail are grooved. The timbers are then passed to the angle saw, where the dump sections are dapped and stacked on a loading dock. When enough timbers are accumulated, they are loaded on push cars distributed along the assembly area. After the crossings are assembled, they are loaded on trams and sent to the treating plant. At the treating plant, the crossings are treated by the open-cell process with 0.750 gal of 70–30 creosote-coal tar solution per cubic foot. When treating is completed, the crossings are loaded in gondola cars and shipped to the locations where orders were placed for this material.

Solid Timber Crossing Installation

The committee inspected a recent installation of a prefabricated full-depth timber crossing at Forbing Road, Ensign, Ark. The two main-line tracks at this crossing were completely rebuilt and ballasted with stone ballast and new 132 RE rail was installed with the joints laid tight. New creosoted ties were installed on 19¼-in centers, fully tie plated and further protected with tie pads. This tie spacing was exact as the holes in the timber sections for the drive spikes are prebored at the fabricating plant. The solid timber crossing sections were then installed in accordance with the Missouri Pacific standard plan for highway grade crossing for heavy vehicular traffic. The timber sections are positioned with a gage so they will be exactly 2½ in from the head of the rail. Holes are drilled in the ties for the drive spikes with an electric drill powered by a portable generator, and the drive spikes are then driven into the ties with a sledge. Three types of ⅝- by 12-in drive spikes were used in this crossing to determine their relative resistance to corrosion. One-third are uncoated (20.6 cents each), one-third are galvanized (27 cents each), and one-third are nickel alloy coated (25.6 cents each).

Labor Cost to Install Prefabricated Crossings

(Compiled from actual cost of 6 crossings located on 5 different divisions in 4 states—1956–1958)

Heavy vehicular traffic—Plan 401.0–E	
Total lin ft	255
Total cost (labor only)	$654.91
Cost per lin ft	$ 2.57
Light vehicular traffic—Plan 401.01–B	
Total lin ft	230
Total cost (labor only)	$593.20
Cost per lin ft	$ 2.58
Cost of asphalt (used with Plan 401.01–B)	
Total lin ft	230
Cost of asphalt (material)	$186.27
Cost per lin ft	$ 0.81
Total cost of labor and material—prefabricated crossings in place exclusive of any required track work	
Heavy vehicular—Plan 401.0–E—per lin ft	$10.82
Light vehicular—Plan 401.0–B—per lin ft	$ 6.72

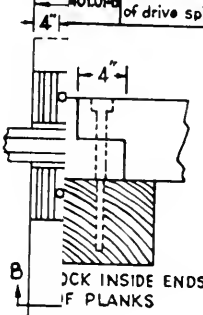
(Text continued on page 400)

RECAPITULATION OF COST OF MANUFACTURING PANEL CROSSINGS AT NORTH LITTLE ROCK, ARK., DECEMBER 1957 THROUGH APRIL 1958

Month	*Number of Crossings*	*Lin ft of Crossings*	*Board ft of Crossings*	*Cost of Timber*	*Cost of Hardware*	*Cost of Manufacture*	*Total Cost*	*Average Cost per M.B.M.*	*Average Cost per Lin Ft*
Light crossings (Plan 401.01-B)									
Dec. 1957	9	464	12,360	$ 912.00	$ 163.37	$ 494.40	$ 1,569.77	$127.00	$3.39
Jan. 1958	9	254	6,525	557.86	89.11	261.00	907.97	139.15	3.57
Feb. 1958	2	38	1,187	93.61	15.24	47.48	156.33	131.70	3.47
Mar. 1958	7	313	7,109	529.60	99.01	284.36	912.97	128.42	2.92
April 1958	4	425	11,026	820.88	153.49	441.04	1,415.41	128.37	3.33
	31	1,494	38,207	$ 2,913.95	$ 520.22	$ 1,528.28	$ 4,962.45	$129.88	$3.33
Heavy crossings (Plan 401.0-E)									
Dec. 1957	37	1,387	78,334	$ 6,312.89	$1,831.66	$ 3,133.36	$11,277.91	$143.97	$8.13
Jan. 1958	34	1,424½	82,612	6,245.28	2,049.02	3,304.48	11,598.78	140.40	8.14
Feb. 1958	21	1,060	61,261	4,782.62	1,558.21	2,450.45	8,791.28	143.51	8.29
Mar. 1958	14	575	32,654	2,522.80	867.08	1,306.16	4,696.04	143.81	8.17
April 1958	19	829	48,491	3,954.67	1,275.91	1,939.64	7,170.22	148.00	8.65
	125	5,275½	303,352	$23,818.26	$7,581.88	$12,134.09	$43,534.23	$143.51	$8.25

Note: Includes cost of treatment.

REVISION RECORD					401.01-B
REVISION			SUPERSEDES		APPROVED
PAGE	DESCRIPTION	DATE	PAGE	FILE Nº	
401.01-B	Addition to notes-lengths of drive spikes shown.	1-20-58	401.01-A	12-3650	W.H.H.



OCK INSIDE ENDS
IF PLANKS

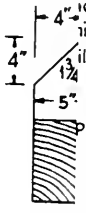
SIZE OF PLANKS AND DRIVE SPIKES

RAIL	PLANKS	DR. SPIKES
90#	SISIE 5¾" x 8¾"	5/8" x 10"
110	" 6⅞" x 8¾"	5/8" x 11"
112-115	" 6⅞" x 8¾"	5/8" x 12"
131-132	" 7½" x 8¾"	" "

TES :

anks to be preframed creosoted red oak or gum.
anks to be pre-drilled-5/8" holes.
ovide interlocking notches on ends of all planks except the
veled end of outside plank.
es within limits of crossing shall be sawed, pre adzed,
eosoted and tie plated.
e spacing shall be 19½".
ld drill 9/16" holes into ties to accommodate length of drive spikes.
terlocked joints to be centered over tie.
ngth of intermediate planks to be 8 feet.
ngth of end planks may be variable but not less than three tie
aces plus one-half width of tie. Increase length of planking
necessary.
here unavoidable adzing and cutting of material is necessary
eat cut surfaces with creosote. Treat holes drilled in field
th creosote.
il anchors normally located within limits of crossing may be
vided equally on adjacent approach rails.
ack between ends of planking and shoulder line of highway
all be filled with ballast material.
less Chief Engineer System instructs otherwise, rail lighter than
)# shall be relaid with 90# or heavier. Where practicable, no
nts shall be permitted in the crossing nor within 6 feet of the
ds of the crossing. Joints which are unavoidable within these
its shall be pressure welded, or laid tight and frozen. Build up
il ends and grind to equal height where required.

5/8" x 10" Was
5/8" x 11"
5/8" x 12"



SECT

PROVED: W. H. Hobbs
CHIEF ENGINEER SYSTEM AND CHAIRMAN COMMITTEE
ON ROADWAY DEPARTMENT STANDARDS

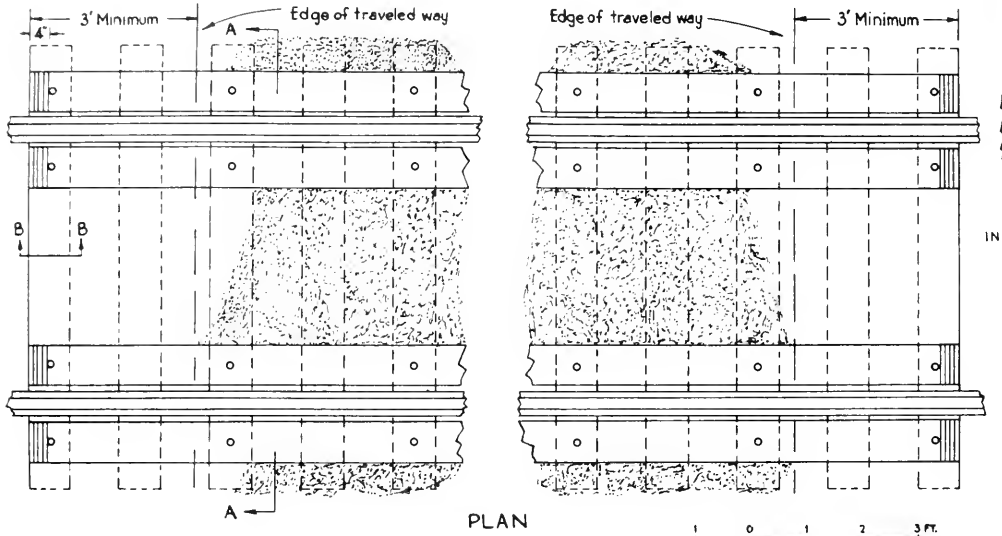
MISSOURI PACIFIC LINES

STANDARD

HIGHWAY GRADE CROSSING FOR MEDIUM AND LIGHT VEHICULAR TRAFFIC

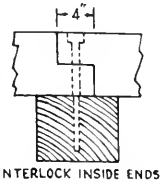
SCALE AS NOTED MAR. 1, 1955
OFFICE OF CHIEF ENGINEER SYSTEM, ST. LOUIS, MO.
PAGE 401.01-B FILE Nº 12-3650

REVISION RECORD					401.01-B
REVISION			SUPERSEDES		APPROVED
PAGE	DESCRIPTION	DATE	PAGE	FILE Nº	
401.01-B	Addition to notes-lengths of drive spikes shown.	1-20-58	401.01-A	12-3650	W.H.H.



PLAN

1 0 1 2 3 FT.

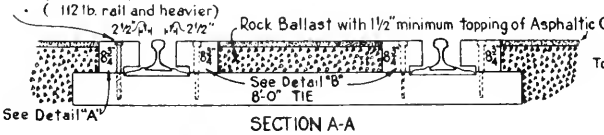


INTERLOCK INSIDE ENDS OF PLANKS

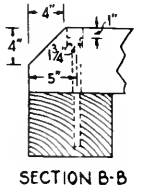
SIZE OF PLANKS AND DRIVE SPIKES

RAIL	PLANKS	DR. SPIKES
90#	SISIE 5¾" x 8¾"	5/8" x 10"
110	" 6⅜" x 8¾"	5/8" x 11"
112-115	" 6⅞" x 8¾"	5/8" x 12"
131-132	" 7½" x 8¾"	" "

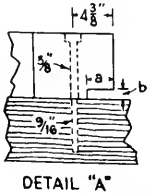
5/8" x 10" Washer Hd. Timber Drive Spike (90 lb. rail)
5/8" x 11" " " " " (110 lb. rail)
5/8" x 12" " " " " (112 lb. rail and heavier)
Every other tie



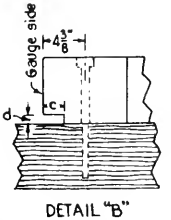
SECTION A-A



SECTION B-B



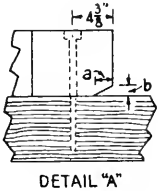
DETAIL "A"



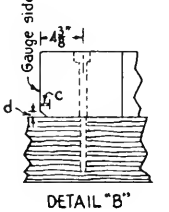
DETAIL "B"

FOR 112 TO 132 LB. RAIL

a	b	c	d
3½"	1 1/16"	2½"	1"



DETAIL "A"



DETAIL "B"

FOR 90 and 110 LB. RAIL

a	b	c	d
2"	1"	7/8"	½"

0 1 FT.

NOTES:

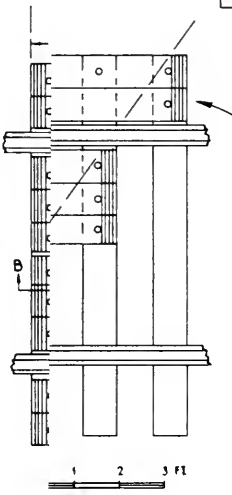
Planks to be preframed creosoted red oak or gum.
Planks to be pre-drilled-⅝" holes.
Provide interlocking notches on ends of all planks except the beveled end of outside plank.
Ties within limits of crossing shall be sawed, pre adzed, creosoted and tie plated.
Tie spacing shall be 19¼".
Field drill 9/16" holes into ties to accommodate length of drive spikes.
Interlocked joints to be centered over tie.
Length of intermediate planks to be 8 feet.
Length of end planks may be variable but not less than three tie spaces plus one-half width of tie. Increase length of planking if necessary.
Where unavoidable adzing and cutting of material is necessary treat cut surfaces with creosote. Treat holes drilled in field with creosote.
Rail anchors normally located within limits of crossing may be divided equally on adjacent approach rails.
Track between ends of planking and shoulder line of highway shall be filled with ballast material.
Unless Chief Engineer System instructs otherwise, rail lighter than 90# shall be relaid with 90# or heavier. Where practicable, no joints shall be permitted in the crossing nor within 6 feet of the ends of the crossing. Joints which are unavoidable within these limits shall be pressure welded, or laid tight and frozen. Build up rail ends and grind to equal height where required.

APPROVED: W. H. Hoover
CHIEF ENGINEER SYSTEM AND CHAIRMAN COMMITTEE ON ROADWAY DEPARTMENT STANDARDS

MISSOURI PACIFIC LINES
STANDARD
HIGHWAY GRADE CROSSING FOR MEDIUM AND LIGHT VEHICULAR TRAFFIC

SCALE AS NOTED MAR. 1, 1955
OFFICE OF CHIEF ENGINEER SYSTEM, ST. LOUIS, MO.
PAGE 401.01-B FILE Nº 12-3650

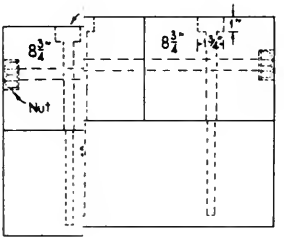
REVISION RECORD					401.0-E
REVISION			SUPERSEDES		APPROVED
PAGE	DESCRIPTION	DATE	PAGE	FILE Nº	
401.0-D	Note (1) and note on joints	2-13-56	401.0-C	A-1552	
401.0-E	Addition to notes - lengths of drive spikes shown.	1-20-58	401.0-D	A-1552	



Length of end sections may be variable but not less than three tie spaces (19¼") plus one-half width of tie. Increase length of planking, if necessary.

SIZE OF PLANKS AND DRIVE SPIKES

RAIL	PLANKS	DR. SPIKES
90 Lb.	SISIE 5½" x 7¾"	5/8" x 10"
	" 5¾" x 8¾"	"
110	" 6⅜" x 7⅜"	5/8" x 11"
	" 6⅜" x 8¾"	"
112 - 115	" 6⅞" x 7⅞"	5/8" x 12"
	" 6⅞" x 8¾"	"
131 - 132	" 7½" x 7¾"	"
	" 7½" x 8¾"	"



NOTE (1)
Emulsified asphalt shall be applied in open spaces around rails when:
1-Crossings are within a populated area and frequently used by pedestrians.
2-Crossing angle with track is less than 70 degrees.

nk sections to be preframed, bolted and drilled - 5/8" holes.
inks to be creosoted red oak or gum.
s shall be 8'-6" long or 8' long staggered 3".
ll 9/16" holes into ties to accommodate length of drive spikes.
s within limits of crossing shall be sawed, pre-adzed, creosoted and tie plated.
spacing shall be 19¼" throughout crossing.
ere unavoidable adzing and cutting of material is necessary treat cut surfaces
h creosote. Treat holes drilled in field with creosote.
il anchors normally located within limits of crossing may be divided equally on
acent approach rails.
ck between ends of planking and shoulder line of highway shall be filled with
ost material.
t of emulsified asphalt to be applied to entire surface of crossing
ediately after installation.
cial plan will be required where crossing is located on curves over 6° or within
its of turnout or other special condition.
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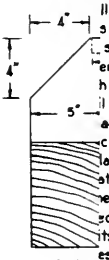
l ends and grind to equal height where required.

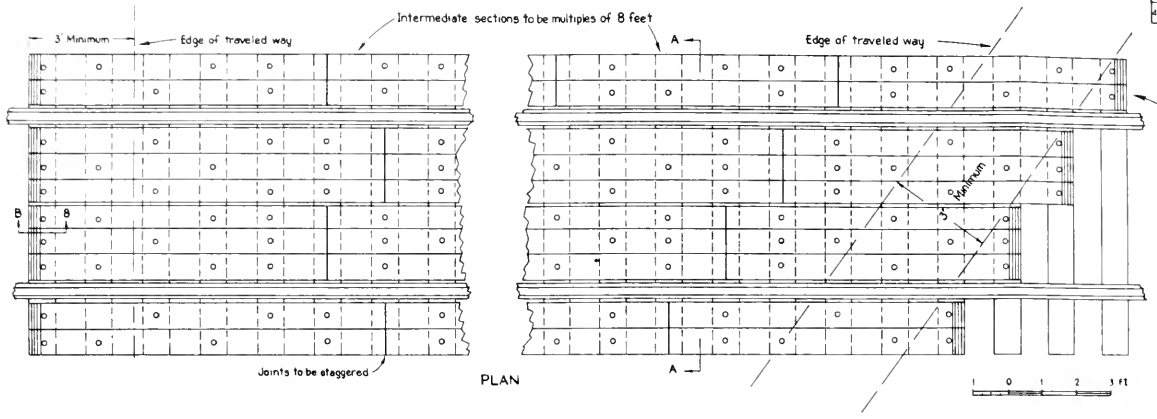


SECTIO

T. Hobby
AND CHAIRMAN COMMITTEE
NT STANDARDS

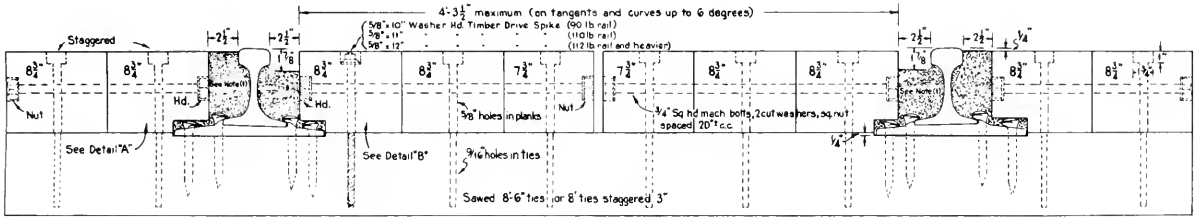
MISSOURI PACIFIC LINES
STANDARD
HIGHWAY GRADE CROSSING FOR HEAVY VEHICULAR TRAFFIC
SCALE AS NOTED
MAR. 1, 1955
OFFICE OF CHIEF ENGINEER SYSTEM
ST. LOUIS, MO.
PAGE 401.0-E
FILE Nº A-1552

REVISION RECORD					401.0-E
REVISION			SUPERSEDES		APPROVED
PAGE	DESCRIPTION	DATE	PAGE	FILE Nº	
401.0-D	Note (1) and note on joints	2-13-56	401.0-C	A-1552	W.T.H.
401.0-E	Addition to notes - lengths of drive spikes shown.	1-20-58	401.0-D	A-1552	W.T.H.



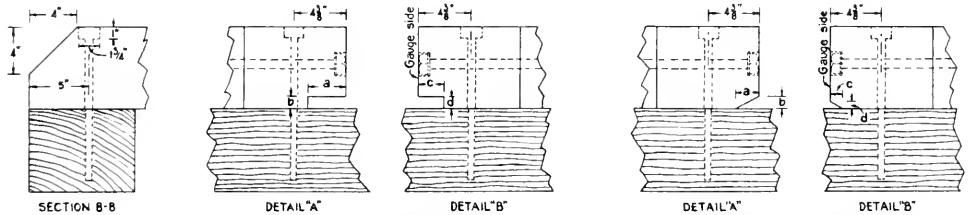
SIZE OF PLANKS AND DRIVE SPIKES

RAIL	PLANKS	DR SPIKES
90 Lb.	SISIE 5"x7⅞"	5/8"x10"
	" 5"x8¾"	"
110	" 6"x7⅞"	5/8"x11"
	" 6"x8¾"	"
112 - 115	" 6"x7⅞"	5/8"x12"
	" 6"x8¾"	"
131 - 132	" 7½"x7⅞"	"
	" 7½"x8¾"	"



SECTION A-A

NOTE (1)
Emulsified asphalt shall be applied in open spaces around rails when:
1-Crossings are within a populated area and frequently used by pedestriens.
2-Crossing angle with track is less than 70 degrees.



FOR 112 TO 132 LB. RAIL

a	b	c	d
3½"	1⅞"	2½"	1"

FOR 90 and 110 LB. RAIL

a	b	c	d
2"	1"	⅞"	½"

NOTES:
Plank sections to be preframed, bolted and drilled - 5/8" holes
Planks to be creosoted red oak or gum.
Ties shall be 8'-6" long or 8' long staggered 3"
Drill 9/16" holes into ties to accommodate length of drive spikes.
Ties within limits of crossing shall be sawed, pre-adzed, creosoted and tie plated.
Tie spacing shall be 19¼" throughout crossing.
Where unavoidable adzing and cutting of material is necessary treat cut surfaces with creosote. Treat holes drilled in field with creosote.
Rail anchors normally located within limits of crossing may be divided equally on adjacent approach rails.
Track between ends of planking and shoulder line of highway shall be filled with ballast material.
Coat of emulsified asphalt to be applied to entire surface of crossing immediately after installation.
Special plan will be required where crossing is located on curves over 6° or within limits of turnout or other special condition.
Unless Chief Engineer System instructs otherwise, rail lighter than 90 lb shall be relaid with 90 lb or heavier. Where practicable, no joints shall be permitted in the crossing nor within 6 feet of the ends of the crossing. Joints which are unavoidable within these limits shall be pressure welded, or laid tight and frozen. Build up rail ends and grind to equal height where required.

0 3 6 9 12 INCHES

APPROVED: W. T. Hagen
CHIEF ENGINEER SYSTEM AND CHAIRMAN COMMITTEE ON ROADWAY DEPARTMENT STANDARDS

MISSOURI PACIFIC LINES
STANDARD

HIGHWAY GRADE CROSSING FOR HEAVY VEHICULAR TRAFFIC

SCALE AS NOTED
MAR. 1, 1955
OFFICE OF CHIEF ENGINEER SYSTEM
ST. LOUIS, MO.

FILE Nº A-1552

Timber preframing mill.

Highway grade crossing for heavy vehicular traffic.

Special Track Gangs

Special track gangs are used to operate power tampers, tie renewal equipment and for other tasks commonly assigned to extra gangs. These gangs vary in size from 10 to 15 men depending on the requirements of the job.

The committee observed the operation of a tie renewal gang while at Forbing Road. The gang consisted of a foreman and 12 trackmen. The ties for renewal were marked by the roadmaster ahead of the unloading train, so the ties were unloaded very close to the point of application. The tie renewal gangs precede and work independently of the surfacing gangs and, as a rule, ties are renewed only where renewals exceed 300 per mile. Section gangs make any spot renewals required. New ties are tamped so as not to impair riding conditions of the track.

The organization of a typical tie renewal gang is as follows:

Operation	*Equipment*	*Force*
Remove spikes from ties to be renewed	Spike puller	1 Trackman
Remove tie plates and anchors from old ties	Hand tools	1 Trackman
Remove old tie	Tie extruder	2 Trackmen
Prepare tie bed and insert new ties, set spikes	Hand tools	3 Trackmen
Hold up ties for spiking	Tie nipper	1 Trackman
Spike new ties	Air-driven-spiker	1 Trackman
Tamp new ties	Air-driven tamper	2 Trackmen
Replace anchors and fill cribs	Hand tools	1 Trackman
	1 Foreman	12 Trackmen

Note: The head-end men, when a sufficient distance ahead, drop back and assist in preparation of tie bed.

The tie renewal gang is so organized that all machines can be removed from the track and replaced by the gang easily and quickly ahead of a train, and very little time is lost clearing for trains. The special track gangs work without flagmen, and train crews are given a train order to reduce speed to 30 mph prepared to stop where gangs are working. The foreman works closely with the tower operator and gives a hand signal to the train crew to proceed when the gang is in the clear.

The following is a typical train order for protecting special track gangs used on the Missouri Pacific.

"Effective 7:30 am until 3:30 pm, May 21, all trains approach tie renewal gang Sedalia sub-division between MP 231–20 and MP 232–20 prepared to stop and proceed on hand signal given with yellow flag by foreman in charge. A speed of 30 mph will not be exceeded within the limits of this order."

CONCLUSION

The Missouri Pacific has programmed the replacement of its worn-out timber trestles with permanent concrete pile and slab bridge construction in a most economical and efficient manner.

The permanency of this type of structure, requiring little or no maintenance, has proved to be a sound investment as compared to the use of timber construction requiring renewals in a continually rising material and labor market. It is concluded therefore, that under conditions similar to those encountered on the Missouri Pacific, substantial labor savings may be realized by the replacement of wooden trestles with those of reinforced concrete design.

This road has also made substantial savings in labor by prefabricating full-depth timber highway crossings at a centralized framing plant.

LABOR COST OF RENEWING CROSS TIES ON EIGHT REPRESENTATIVE LINE DIVISIONS JANUARY TO APRIL 1958

Division and District	*Days Worked*	*Number of Ties*	*Total Man-Hours*	*Labor Cost*		*Average Number of Ties per*	
				Total	*Per Tie*	*Man Day*	*Gang Day*
				Power Tools			
Eastern	91	18,677	8,833	$16,996	$0.91	16.9	205
Omaha	15	3,130	1,700	3,243	1.03	11.7	209
Kansas	31	4,906	3,224	6,095	1.24	12.2	158
Western District	137	26,713	13,757	$26,334	$0.99	15.5	195
Arkansas	145	26,026	19,182	$36,875	$1.42	10.7	179
Louisiana	164	36,571	20,107	38,223	1.05	11.6	223
Southern District	309	62,597	39,589	$75,098	$1.20	12.7	202
Palestine	208	34,130	21,673	$41,087	$1.20	12.6	164
Kingsville	79	15,271	8,653	16,613	1.09	14.1	193
DeQuincy	76	16,343	8,301	15,526	0.95	15.7	215
Gulf District	363	65,744	38,630	$73,226	$1.11	13.6	181
Total	809	155,054	91,976(a)	$171,658(b)	$1.13	13.19	192
				Hand Tools			
Western District	5	730	760	$ 1,128	$1.96	7.7	146
Southern District	28	3,159	3,051	5,779	1.83	8.3	113
Gulf District	68	7,170	7,168	13,487	1.88	8.0	105
Total	101	11,059	10,979	$20,694	$1.87	8.06	109
Difference					$0.71	5.43	83

Notes: (a) Includes time for foremen.
(b) Includes cost of fuel, oil and field repairs for power tools.

The Missouri Pacific has progressed the design of new equipment and machines, such as the tie car and spiking machine, that have been effective in the economical use of maintenance of way forces.

Report on Assignment 3

Labor Economies to Be Derived from Cyclic Maintenance

H. W. Seeley (chairman, subcommittee), A. D. Alderson, V. A. Barnhart, Jr., R. H. Carpenter, W. E. Chapman, S. A. Cooper, P. A. Cosgrove, C. G. Davis, R. A. Gravelle, E. B. Harris, W. H. Hoar, N. M. Kelly, J. S. McBride, H. C. Minteer, R. W. Preisendefer, E. J. Sierleja, A. H. Stimson, J. T. Sullivan, F. R. Woolford.

Your committee submits the following final report as information.

In considering this subject, reference should be made to a report on a similar assignment published in the Proceedings, Vol. 57, 1956, page 417.

The information for the following report was obtained from a questionnaire that was answered by 29 railroads. The replies indicated that 22 of these railroads have adopted some form of cyclic maintenance, while 7 have not. Of the 22, 12 roads report that their tie renewal and smoothing or surfacing operations are completely mechanized, and 10 report that on their lines these operations are partly mechanized. Of the 7 railroads reporting that they are not using cyclic maintenance, 3 report that these operations are partly mechanized and 4 indicate that they have mechanized to only a small degree. Twelve roads report that they started their cycle program prior to 1956; 5 started in 1956; 3 in 1957; and 2 in 1958. Only 3 of the railroads replying to the questionnaire indicated that they had completed a full tie renewal and surfacing cycle.

There is considerable variance as to the degree to which various roads have adopted the cyclic method of programming maintenance work, and the length of the cycles used or anticipated vary considerably. However, they fall generally into four groups:

1. A few railroads have arbitrarily adopted a tie renewal cycle which varies from two to seven years and an out-of-face surfacing cycle of from two to ten years. The length of the cycle was determined as the result of past experience and consideration of the tonnage, speed of trains, and class of traffic, and will be adjusted from time to time, based upon the results after the first cycle is completed.
2. Another group has adopted a tentative cycle length which is based upon working the track when the tie renewals needed are about equal to the number of ties per mile that their mechanized tie gang will renew most economically. Between tie renewal cycles, some of these roads also have an out-of-face surfacing cycle.
3. Several roads have based the length of the cycle upon the length of time that the track can be maintained with a minimum amount of spot surfacing. Tie renewals are made each time that the track is surfaced out-of-face.
4. Some railroads, while they do a complete tie renewal and out-of-face surfacing job with mechanized gangs when working a section of track, and in that respect are following the cyclic maintenance principal, have not established any regular cycle frequency. They program the work when necessary, as determined by periodic inspection.

It is impossible to arrive at any reliable quantitative conclusion as to the labor economies to be derived from cyclic maintenance because:

1. Very few railroads have used cyclic maintenance long enough to determine the economic length of the cycle.
2. The cyclic method of maintenance has probably greatly increased the savings that were first made possible by mechanization, but most railroad cost information is not detailed enough to separate the savings that can be attributed directly to mechanization from the savings resulting from cyclic maintenance.
3. During the period of change-over to mechanized cyclic maintenance, there is a certain amount of rehabilitation work as well as some temporary carry-over work that must be done, and this tends to distort any cost figures that may be available.

However, based on the opinion of the 29 railroads that furnished information for this report, the following conclusions may be reached as to what savings may be anticipated when cyclic maintenance is established:

1. The resulting more uniform quality track and better general standard of maintenance which results should reduce the amount of labor required for spot surfacing and spot tie renewals.
2. The necessary long-range programming and budgeting will result in reduction in inventory, savings in labor for material handling, more stable force and greater utilization of available machinery. On the other hand, short-term programming and budgeting may disrupt this type of maintenance program to the extent that much of the economy would be lost.
3. Fewer gangs and working units will permit closer supervision and better organization, resulting in increased production per man and possibly will result in a reduction in the amount of supervision required.
4. Fewer gangs, on some railroads, will cause less traffic interference and may make it possible for operating departments to permit more uninterrupted working time, resulting in an increase in production per man.

SUMMARY

Most railroads that have adopted cyclic maintenance methods, appear to be progressing toward establishing a length of cycle for out-of-face surfacing which will eliminate, or at least reduce to a minimum, the need for intermediate spot surfacing. Also, they anticipate making necessary tie renewals at the time that out-of-face surfacing is done, thus causing the tie renewal cycle to coincide with the out-of-face surfacing cycle.

The physical condition, the riding quality, and the standard to which it is desirable and economical to maintain these conditions will generally be dependent upon the tonnage, speed and class of traffic that the track will carry and will determine the length of the maintenance cycles. Once the cyclic method of maintenance is established, the greatest economy that can be directly attributed to it will result from correctly determining the most economical length of cycle necessary to maintain the railroad to the standard required and, at the same time, to permit the work to be accomplished economically with the organization and equipment that is available.

Report on Assignment 4

Relative Advantages of Renewing Ties in Advance of Out-of-Face Surfacing with a Mechanized Tie Gang, Compared with Renewing Ties with a Surfacing Gang

Claude Johnston (chairman, subcommittee), A. D. Alderson, R. M. Bailey, E. J. Brown, R. H. Carpenter, A. B. Chaney, W. E. Chapman, P. A. Cosgrove, L. R. Deavers, M. H. Dick, W. M. S. Dunn, J. E. Eisemann, J. L. Fergus, R. A. Gravelle, Gene L. Harris, R. J. Hollingsworth, T. B. Hutcheson, H. W. Kellogg, J. R. Miller, R. W. Pember, M. S. Reid, H. W. Seeley, R. G. Simmons, W. H. Vance, F. R. Woolford.

When ties are installed in advance of a surfacing operation, no slow order is required. Also, the tamping operation is not delayed by tie renewal work. However, when ties are installed with a surfacing operation, the supervision problem is simplified, as one supervisor can handle the entire operation. One operation is more economical than two separate operations.

These "relative advantages" and other information for this report were developed from a survey of 66 railroads in the United States and Canada.

The respondents were divided equally between those who favored renewing ties in advance of surfacing and those who preferred to renew ties with the surfacing gang. Each group claimed that the method they use offers advantages for their particular situation.

Questionnaire Results

A total of 37 railroads replied to the questionnaire, but five did not complete the questionnaire. Of the 32 roads furnishing information, 14 stated that they renew ties in advance of surfacing and 14 stated that they renew ties with surfacing. Of the 14 roads which use the "advance" method, 11 install ties with mechanized gangs on main track, with some installations by hand on branch lines. Three of these railroads install ties entirely by hand.

Two railroads, each with annual tie programs divided about equally between heavy and light tie replacements, claimed this condition influenced them to renew ties in advance. Those roads with light tie renewals stated that frequency of renewal did not influence them as to the choice of method.

Some of the roads reported that they do not raise the track for tie replacements, while others reported a raise ranging from 1 to 5 in. Five railroads stated that the amount of raise influenced their choice as to the method used, with light raises confined generally to mechanized operations. Nine roads reported that the amount of raise has no relation to the method used.

Eleven of the railroads renewing ties in advance are predominately single-track lines. Only two of this group are largely double-track roads.

In replying to a series of questions designed to develop how track is occupied by track forces and the method of protection used, only two railroads stated that these factors had any bearing on their choice as to method of installing ties. Twelve railroads reported that these factors had no bearing on the method used.

All of these railroads in this category occupy track between trains by communication with train dispatcher. Only one reported having work time assigned in CTC territory. Three reported that they occupy track under special rules in CTC territory.

Gang size varied from 6 trackmen to 35 trackmen and foreman, with 7 roads using an assistant foreman. The number of machine operators used varied from one to nine.

Eight railroads reported costs ranging from 0.50 to 1.00 man-hours per tie, for tie installations only. Five reported costs for advance tie replacements plus follow-up surfacing which ranged from 0.90 to 4.0 man-hours per tie.

Seven railroads reported that they follow up with surfacing operation as soon as possible after ties are installed; others allow from 1 to 3 months between.

Five railroads replied that the delay time between tie installation and surfacing operation allows ties to become more firmly bedded, which provides better track condition and lengthens periods between surfacing and smoothing cycles. Six railroads stated that this result was not apparent.

A random sampling of the "relative advantages" suggested by the railroads installing ties in advance of a surfacing gang is as follows:

"Tie gang has time to work road crossings and hand-tamp switches."
"Permits small number of men for mechanized tie gang."
"Surfacing done on track where required by surface conditions and not tie renewals."
"..... difficult to synchronize the production of our tie installing and tamping machines."

The second group of 14 railroads reported renewing ties with a surfacing gang. All of this group stated that they are mechanized. These roads indicated that frequency of tie renewals did not influence their choice of method. However, all reported relatively light tie renewals and a program of cycle maintenance.

It is apparent that there is more uniformity in the amount of track raise reported by this group. Most reported a raise of 1½ to 3 in, while one road uses a raise of 6 in. The majority stated that high raises are not satisfactory for mechanical tampers. Most of this group unload ballast before surfacing.

This group is evenly divided between those being predominately single-track railroads and double- or multiple-track railroads.

This group of respondents indicated that such factors as occupancy of track, method of protection and being single- or double-track lines, did influence their choice as to method of operation. Most stated that they are required to communicate with the train dispatcher for occupancy of track. Five stated that they are given assigned hours on track. Some of this group work track under the detour method. Because of the added surfacing operation, gang size reported is larger. Track gangs vary from 4 to 26 men. One road reported using 80 trackmen in timbering and surfacing gang. This gang does not use power tampers, but does tamp track with hand-held power tools. The number of machine operators used vary from 2 to 17. All roads employ from two to three assistant foremen in each gang. Eight roads reported that gangs work under the direct supervision of a supervisor while six stated that the surfacing gang is directed by a foreman.

Costs reported by 13 railroads varied from 0.42 to 1.9 man-hours per tie for complete operation of timbering and surfacing.

More than 75 percent of the respondents listed the advantages of installing ties with a surfacing gang. Here is a random sampling of their reports.

".....lowest cost per tie and complete the entire working of piece of track in one operation."
"A lag (between tie insertions and surface) induces rougher riding and would shorten smoothing or surfacing cycle."

"Lower cost for supervision, flag protection, etc."
"In double-track territory it decreases length of time single-track operation is required."

From the response to the questionnaire it would seem that neither method has any particular advantage over the other; however, an analysis of the replies to specific questions on each method reported used does tend to reveal that under certain conditions, each method offers advantages to the user. From the stand point of cost per tie installed, the combined timbering and surfacing operation is more economical. However, these figures represent direct labor costs and do not take into consideration the cost of ownership of equipment for a large mechanized gang. Such items as depreciation, interest on investment, repair and maintenance costs would materially increase the cost per tie installed.

To apply a meaningful comparison of costs between the two methods would require a system of measurement that would evaluate the many variables that are present on different railroads.

From the response to questions relating to factors that could influence a choice of method in timbering and surfacing it is significant that more than 50 percent of the railroads had made an effort to tailor the method to the circumstances peculiar to its own property.

A respondent, an all single-track railroad, stated: "We believe that the best job with the least train delay is performed when ties are installed with surfacing."

Another railroad, 80-percent double- or multiple-track, stated: "It is our general over-all opinion that on double- and multiple-track territories where detour interlocking stations and crossovers are available, installing ties with a surfacing gang is superior. Installing ties in advance of the surfacing gang is far superior on single-track territories where it is necessary to continually put on and take off all of the machinery that would be used in making installations with surfacing gangs."

Negative factors reported in the survey were: lack of power-tamping equipment and improper coordination of track work with train movements.

CONCLUSIONS

From the replies to questions on this assignment, it may be concluded that advantages can be derived from either method. However, before these advantages can be realized, all factors influencing the operation must be analyzed. If the method of operation can be tailored to meet the circumstances that exist on each road, the method offering the most advantages can be chosen.

This report is presented as information, with the recommendation that the subject be discontinued.

Report on Assignment 5

Labor Economies to Be Effected Through the Use of Power Tools and Mechanized Equipment by Bridge and Building Gangs

W. E. Chapman (chairman, subcommittee), A. D. Alderson, R. M. Bailey, W. H. Brameld, R. H. Carpenter, B. S. Converse, C. G. Davis, L. R. Deavers, M. H. Dick, L. E. Donovan, W. M. S. Dunn, J. L. Fergus, R. T. Fortin, R. L. Fox, W. H. Hoar, N. M. Kelly, C. T. Popma, F. R. Spofford, John Stang, A. H. Stimson, W. H. Vance, H. E. Wilson.

Your committee submits the following report of progress in determining the labor economies to be effected through the use of power tools and mechanized equipment by bridge and building gangs.

This, of course, in view of increased cost of materials and labor, and the need for keeping outgo of monies within the limits of income, is a very pertinent subject and of interest to all carriers.

Because of the voluminous material that would be required to cover all tools, large and small, this report covers only those tools found by certain reporting carriers to be the most economical.

While this report refers primarily to maintenance, the tools and equipment described are also economical in construction work.

UNLOADING BRIDGE MATERIAL AT SITE OF USE BY BRIDGE HOIST OR CRANE

The material for each structure is banded or bundled separately, each bundle being marked prominently with its designated structure number. Then it is loaded at the treating plant or storehouse so that the material for the first structure reached by train (local freight when available, otherwise a work train) will be the top bundle or bundles. Then the next bundle or bundles to the second trestle or structure, and so on.

These bundles of material are unloaded at each structure by a bridge hoist or crane under the supervision of the bridge and building supervisor. This operation is scheduled so that the material will be unloaded just before the gangs arrive at the structure to begin work.

Comparison of the cost of handling materials in this manner with the cost of handling material by loading in cars unclassified, placing at nearest siding, unloading, stacking and then later hauling to the site of the work by push car or truck is shown below:

Unloading 349 pieces of treated timber, 20.625 MBM, plus 484 lin ft of treated piling with work train and dragline at 22 trestles in a distance of 63 miles—

1—8 hr work train day
1—8 hr day for operator
1—8 hr day for one laborer
1—day of b&b supervisor's time

Additional cost of banding material at treating plant—Unloading by b&b gangs at six stations, stacking and later hauling out to trestles as needed—

64 man-hours, foreman
384 man-hours, bridgemen

No cook's time included, as all carriers do not provide cooks. Too, material cars are eliminated.

TOOLS AND EQUIPMENT FOR VARIOUS TYPES OF GANGS AND RESULTING ECONOMIES

Timber Bridge Gang

1. One hydraulic hoist mounted on a heavy-duty truck with the following equipment and features: telescoping boom (16 to 24 ft), mounted on a 360-deg pivot, swinging through an 85-deg vertical plane, with two load lines capable of lifting 1200 lb each; two hydraulically operated outriggers; four manual rail clamps; five-speed transmission with full high-speed reverse; expanded metal floor; hydraulically operated retractable flanged rail wheels; 2½-in ball trailer hitch for handling house trailer; points on four corners for attaching snatch blocks which serve the same purpose as a winch on the front and rear of the machine. All hydraulic controls should be easily accessible to the operator who also has remote control of truck from his hoist operating position. The truck should be capable of highway speeds over 40 mph (minimum state speed on some roads) while towing trailer. Two power outlets from hydraulic plant on truck and so built that boom will not extend beyond front bumper of the truck when traveling.
2. One hydraulic chain saw, which will work under water.
3. Four hydraulic jacks.
4. One hydraulic bolt puller.
5. One hydraulic bolt cutter.
6. One hydraulic auger or drill.
7. One hydraulic impact wrench.
8. One hydraulic hammer.
9. One hydraulic power source capable of operating any four tools at the same time.
10. One bridge master.

With the above tools and equipment, all timber bridge work, such as replacing timbers, lining track, pulling in braces, lining piling, placing material at exact spot needed and transporting material throughout the length of trestle, can be done.

The above tools and equipment have increased production 3.45 times. For example, using this new equipment, an inside open-deck stringer can be replaced in less than 35 min instead of the 75 to 80 min previously required.

The larger roads have specialized gangs, some working bridge timbers from the caps up, and others working from the caps down. Smaller carriers have gangs that do all the work with the above equipment.

Steel and Concrete Bridge Gangs

1. One bridge hoist mounted on truck as for timber bridge gang and/or one locomotive crane.
2. One air compressor with all types of air tools for both concrete and steel work.
3. One set of portable platforms and scaffolding.

These gangs purchase ready-mixed concrete when available. Some ready-mixed concrete has been delivered to practically inaccessible locations and over distances of 30 miles or more.

Production has been doubled by the use of the above equipment and tools.

Bridge Greasing Gangs

1. One production spraying machine, with retractable flanged rail wheels, speed in excess of 40 mph minimum highway speed, self propelled, capacity of six 55-gal drums, thermostat controlled heating system to warm the material to be sprayed and with power to operate eight regular paint guns or three grease material guns.
2. One set spider staging and scaffolding.

With this equipment, about six times as much structural steel has been greased as was being done with brush painting. This is due to the increased speed of the greasing equipment plus the fact that greasing is a one coat operation requiring a minimum of pre-cleaning. The above equipment used for greasing structural steel reduces the over-all cost to about 17 percent of that required for painting, and provides equal protection for a comparable period of time.

Bridge Deck Coating Gangs

1. One production spraying machine, with retractable flanged rail wheels, speed in excess of 40 mph minimum highway speed, self propelled, capacity of six 55-gal drums, remote control of machine on one of the three pole guns, thermostat controlled heating system to warm the material to be sprayed, power to operate eight regular paint guns or three asphaltic material guns.
2. One gravel distributing attachment, capacity of 4½ cu yd, adjustable up to 12 ft in width.

This equipment makes possible an increase in production up to 2½ times that of previous machines.

For example: the tops and ends of ties, tops of stringers and caps on a 315-ft open-deck trestle were coated with an asphaltic, asbestos compound and roof gravel in 70 min. A 186-ft open-deck trestle was coated in the same manner in about 45 min.

The larger carriers have gangs equipped as above that specialize in deck coating only, whereas shorter roads combine this type of work with other spraying operations, using the following equipment:

1. One hydraulic aerial boom mounted on heavy-duty truck as for timber gangs, with heating and spraying equipment and gravel distributing attachment.
2. One air compressor with all types of air tools for both steel and concrete work.
3. One set spider staging and portable platforms.

Spraying structural steel and coating decks are generally done during the warmer months and bridge repairs made during the cold months. Therefore, all of the equipment, with the exception of the sprays and pumps, are used throughout the year.

The average increase in production derived from this equipment, for all types of work, is about three-fold.

Building Paint Gangs

1. One heavy-duty truck with outriggers on which is mounted two 55-gal airless spray outfits and one 55-gal spray outfit for roof coating and other metal preservatives that must be heated.
2. Hydraulic aerial boom, mounted on the truck, with a work basket for carrying two men up, out, over and down to a distance of 48 ft from the base of the boom, operated by men in the basket by means of three levers. The mast will pivot the boom 360 deg horizontally. The inner boom can be swung through an 85-deg vertical plane, and the outer section of the boom positioned anywhere within a 265-deg vertical plane. With the above equipment, eight times as many yards of wall area can be painted as can be done with scaffolds.

Carpenter Gangs

1. One carpenter trailer, enclosed on all sides and arranged so that the sides can be raised to form a roof over the trailer floor which serves as a work bench.
2. One power plant for furnishing power for various power tools.
3. Power saws, drills, joiners, planers and other power, hand-held carpenter tools.

This equipment is producing 2½ times the amount of work done previous to the use of such equipment.

All of the gangs mentioned are housed in highway trailers. The gangs that are not provided with one of the specialized trucks are assigned a conventional heavy-duty truck to handle their trailers. This enables the gang to be camped at the site of the work in most cases. Therefore, they only have to walk out of their trailers to be on the job.

All gangs are equipped with radios for instant communication with their supervisors, approaching trains and with other forces if necessary.

CONCLUSIONS

Many combinations of the equipment and tools described above can be made. The combination and make-up of the gangs depend upon the size of the carrier, their contractural requirements and also their particular maintenance requirements.

One of the most important results of mechanization is the realization of the full abilities of men throughout the entire working day, as the addition of machines has practically eliminated all arduous labors.

The over-all reduction in bridge and building expenses due to the acquisition and use of the above described tools and equipment approaches 70 percent.

Report on Assignment 6

Labor Economics to Be Derived from the Use of Radio by Maintenance of Way Gangs

H. M. Williamson (chairman, subcommittee), R. M. Bailey, W. H. Brameld, A. B. Chaney, B. S. Converse, C. G. Davis, L. R. Deavers, W. M. S. Dunn, H. J. Fast, R. T. Fortin, R. L. Fox, R. A. Gravelle, Gene L. Harris, H. W. Kellogg, R. L. Mays, J. R. Miller, C. T. Popma, H. W. Seeley, E. J. Sierleja, R. G. Simmons, John Stang, A. H. Stimson, W. H. Vance, C. R. Wright.

Information developed at this time discloses that there was nothing new in this field since the last AREA report on the subject (Proceedings, Vol. 59, 1958, pages 590 to 592, incl.).

It is the recommendation of your committee, therefore, that this subject be discontinued for a period of several years, at which time it should be renewed.

Report on Assignment 7

The Specific and Ultimate Improvements in Various Types of Track Maintenance Equipment that Would Provide the Greatest Economies in Maintenance Practices, and How These Potential Economies Would Compare with Present Costs

Collaborating with Committee 27

P. A. Cosgrove (chairman, subcommittee), L. A. Loggins, Lem Adams, J. E. Eisemann, V. A. Barnhart, Jr., J. F. Beaver, S. A. Cooper, L. E. Donovan, R. L. Fox, V. C. Hanna, E. B. Harris, T. B. Hutcheson, N. M. Kelly, H. C. Minteer, G. M. O'Rourke, R. R. Pregnall, Jr., J. S. Snyder, J. T. Sullivan, H. J. Weccheider, H. E. Wilson, C. R. Wright.

This is a progress report, submitted as information.

Thirteen railroads replied to a questionnaire sent to 40 roads requesting recommendations covering improvements in track maintenance equipment which would provide economies in maintenance practices.

Listed below are the improvements recommended:

Multiple Power Tampers

a. Develop an off-track multiple power tamper. Estimate 10 percent reduction in expenses.

b. Develop on-track tamper with rubber tires and adjustable guide wheels which can be easily removed from the track and driven to another location. Estimate 20 percent savings.

c. Construct tampers so they may be swung onto and off the track by cranes. Unable to estimate savings.

d. Develop set-off equipment designed to be an integral part of the machine. Save at least 10 percent.

Spot Tampers

a. Develop small lightweight spot tamper designed to accomplish tamping on both rails. Save 24 man-hours per day.

b. Work toward simplicity so the machinery is not so complicated. Increase productive time.

Power Jacks

a. Consolidate jack, tamping and lining attachments into a single unit. Unable to estimate savings.

b. Increase speed and power of present jacks to permit them to stay ahead of multiple power tampers. Save an estimated 8 man-hours per day.

Spike Setting Machines

a. Develop machine so a keg of spikes can be dumped into a hopper and spikes can be set automatically. Estimate 50 percent reduction in present expense.

b. Attach automatic spike setters to present spike drivers. Save 24 man-hours per day.

Rail Anchor Applicators

a. Equip with hopper and automatic feed to hang anchors. Save $20 per day.

Ballast Cleaners

a. Develop off-track unit to provide mobility as well as more work time without train interference. No estimate made of savings.

b. Develop machine to clean under and between ties. Cost reduced 25 percent.

Detector Cars

a. Either magnetic or induction type should be wired so the detection of a defect would register a signal along with the indication shown on tape. Unable to estimate savings.

Bolt Machine

a. Machine to handle four to six bolts in joint at one time. Reduce present cost 70 percent.

Brush Cutter

a. On-track cutter with hydraulic cutting arms to be used in rough terrain. Estimate 30 percent savings on present cost.

Tie Remover

a. Provide a mechanized rail clamp to be applied by operator, replacing present chains and hooks. Estimate 50 percent savings on present cost.

b. Attach to tie bed scarifier. Save 16 man-hours per day.

Surfacing Device

a. Use electric eye. Save 16 man-hours per day.

Curve Lining Instrument

a. Provide electric device for measuring, recording and computing revised ordinates on curves. Estimated saving of 40 man-hours per day.

Tie Plug Applicator

a. Automatic hopper-type feeder and driver. Save 65 percent of present cost.

Combination Tie Nipper, Spike Setter and Driver

a. For use with under-track plow or sledge as well as with steel gang. Save approximately 80 man-hours per day.

CONCLUSION

The committee realizes that there are machines available equipped to perform some of the tasks mentioned in this report; however, the suggestions were not deleted in the interest of possible further refinement. The estimated economies to be derived from the recommended improvements are individual suggestions of the reporting railroads. All are in agreement that increased production with reduced cost per unit of work accomplished would be obtained by the continued development of ideas such as those presented in this report.

Report on Assignment 8

Labor Economies to be Derived from the Use of Various Machines Available for Calculating and for Lining Curves

M. B. Allen (chairman, subcommittee), L. C. Gilbert, Lem Adams, A. B. Chaney, M. H. Dick, H. J. Fast, R. T. Fortin, Gene L. Harris, W. W. Hay, W. H. Hoar, R. L. Mays, J. R. Miller, C. T. Popma, R. R. Pregnall, D. E. Rudisill, E. J. Sierleja, J. S. Snyder, F. R. Spofford, H. J. Weccheider, H. M. Williamson, C. R. Wright.

This is a final report, submitted as information.

A questionnaire was sent to the chief engineers of 72 railroads in the United States and Canada, and the following is a summary of information furnished by the 45 roads which replied.

As was anticipated, very few railroads have made any comprehensive time studies in connection with lining curves, either of the time required to set stakes or determine throws, or of the actual time involved in shifting the track. In order to determine what economies might result from the various machines available for calculating and for lining curves, it was thought necessary to determine how stakes are set or throws determined and what use is made of power lining machines and the conditions under which they are used.

Five of the roads report they use a transit for setting stakes on all curves. The remaining 40 report they use stringlining principally, although some make occasional use of a transit where shifts are beyond the acceptable limits of stringlining. The replies indicate that stringlining is used on approximately 90 percent of all main-track curves.

Of the roads using stringlining, 55 percent use mechanical full-throw computers, 25 percent use the so-called Bartlet or half-throw method, 15 percent use a full-throw method sometimes called the Snyder bracket system, and the remaining 5 percent compute their throws using a center-of-gravity system and a new graphic system. Half of the computations are made in the field and half in the office, generally by rodmen, instrumentmen or higher classified engineering department employees, and roadmasters or track supervisors. No time studies have been made of the computing or calculating

time, but there is a unanimous agreement that mechanical and graphic computing is twice as fast as mathematical computing, and that stringlining is three or four times faster than transit staking. Because of the increased speed of mechanical or graphic computing, the use of machines results in a 50 percent reduction of labor in determining throws. Also, the throws resulting from the use of machines are usually considerably smaller than throws resulting from mathematical computing, and this results in considerable labor economies in actually shifting the track.

Stakes are set on approximately two-thirds of the mileage, and throw meters are used on the remaining third. Stakes have the following advantages: they can be used from time to time in rechecking a curve, they provide a semi-permanent center line monument, they can be reused when it is necessary to recompute the curve, and they can be set at any time ahead of programmed work. There are also the following disadvantages: they are expensive to install, they create a possible stumbling hazard, and they interfere with the use of mechanical on-track equipment, particularly a ballast regulator.

About half of the railroads use throw meters to some extent and, as mentioned before, approximately one-third use them 100 percent and set no stakes. It is estimated that their use will result in savings of labor of 25 percent, and the expense of the stakes themselves is entirely eliminated.

About one-fourth of the railroads use a mechanical device for measuring ordinates. Generally, two men are used in measuring ordinates with this device, which results in a saving of one-third of the labor required compared with the conventional use of three men, two holding the cord and one measuring the ordinates.

Approximately half of all curve lining is done by power machines of various makes, and the other half of the lining is done by manpower. One-fourth of the railroads reporting use manpower only, one-fifth use machines only and 60 percent use both manpower and machines in varying degrees. Two general types of power lining machines are in use—on-track machines and portable machines (portable machines being defined as relatively small machines which can be removed from their position in the track at any location at which they are being used and on-track machines being defined as those which require either a siding or a special set-off for their removal from the track.) These are generally used in conjunction with other machines in out-of-face surfacing and timbering operations. This is particularly true of the on-track type machines which are seldom used singly in touch-up or spot lining. Several railroads report the efficient use of portable machines for touch-up and spot lining. When on-track machines are used as single units, 70 percent of the railroads use two maintenance-of-way employees as flagmen and 30 percent use two operating department employees for protecting these machines. Flagmen are not generally used with portable lining machines when being used as single units, as one of the men required for their use usually serves as a lookout. Three roads do not use flagmen as they protect their lining operations by radio, train order or track out of service.

The savings which may result from the use of power lining machines may vary considerably, depending upon how the machines are used. If they are used in conjunction with other machines, no flagman, other than those used for the entire operation, are required and the lining may be done using one, two, three or four men in place of perhaps 10 to 15 men required using manpower. If on-track machines are used singly, the expense of the machine, the foreman, the flagman and operator may closely approximate the cost of doing the work by manpower. Portable lining machines are more

adaptable to single use, as no flagmen are generally required and such use results in approximate savings of 40 percent as compared with lining with manpower.

During the past year an attachment has been developed for an on-track lining machine which permits the lining of curves without computing throws or shifts. Also during the past year a new graphic system has been developed for computing half throws without the use of any numbers or computations. Both the curve lining attachment and the graphic computing machine are now in use on several railroads and if they prove satisfactory over a period of time, may in the future affect or change present curve lining practices. Sufficient information is not available at this time to determine the ultimate labor economies which may result from the use of these two machines.

CONCLUSIONS

The replies indicate general agreement on the following:

The use of either mechanical or graphic computing machines for calculating curves results in a 50 percent reduction in the labor required to determine throws as compared with mathematical computing. The use of power lining machines results in a 60 percent reduction in the labor required to line track as compared with the use of manpower.

Report on Assignment 9

Relation Between the Nature of Traffic and the Interval Between Out-of-Face Resurfacing of Tracks of Relatively Similar Characteristics

R. W. Pember (chairman, subcommittee), Lem Adams, L. E. Donovan, W. M. S. Dunn, H. J. Fast, L. C. Gilbert, R. J. Hollingsworth, Claude Johnston, H. E. Kirby, R. L. Mays, J. S. McBride, R. R. Pregnall, Jr., R. W. Preisendefer, D. E. Rudisill, R. G. Simmons, F. R. Spofford, John Stang, J. T. Sullivan, W. B. Throckmorton, H. M. Williamson, H. E. Wilson.

This is a progress report, presented as information.

A questionnaire was submitted to the chief engineers of 49 railroads in the United States and Canada and replies were received from 34. Of the 34 replying railroads 10 were either resurfacing track by hand or had no information available concerning the interval between out-of-face resurfacing operations.

Due to the many variables of climate, basic track structure, speeds, types of traffic, terrains and tonnages on the various railroads spanning this continent, your committee has presented the information received from the above mentioned questionnaire in tabular form to enable the reader to make his own comparisons as to similar characteristics in regard to his own or other railroads.

To increase the length of time between out-of-face resurfacing of track, 12 railroads indicated they are staying abreast of new developments in tamping machines and expanding the use of them on their railroads; six indicated they are installing and expanding the use of spot tampers; while one reports discontinuing smoothing rather than increasing the time between out-of-face resurfacing. Nine railroads are using an improved grade of ballast, six railroads replied they are laying heavier rail, and five are expanding their welded rail program.

Other practices designed to increase the interval are: using a better grade of ties, improving drainage, roadbed stabilization, ballast cleaning, and enlarging the ballast section, the use of ballast drainage cars, improving joint conditions, rail grinding, welding of engine burns and rail ends, and weed control.

SUMMARIES OF REPLIES TO QUESTIONNAIRE

Name of Railroad	Maximum Speed Pass ML	Pass BL	Freight ML	Freight BL	Weight of Rail ML	Weight of Rail BL	Percent Welded or Frozen Jt. Const. ML	Percent Welded or Frozen Jt. Const. BL	No. of Anchors per Panel ML	No. of Anchors per Panel BL	No. Ties per Panel ML	No. Ties per Panel BL	Type Ballast Used ML	Type Ballast Used BL	Max. Raise (in) during Resurf'ing ML	Max. Raise (in) during Resurf'ing BL	Percent Predominate Type Traffic: Mdse	Coal	Ore	Oil	For. Prods.	Mine Prods.	Per-ish.	Agri.	Misc.	Terrain (Percent): Moun-tainous ML	Moun-tainous BL	Rolling ML	Rolling BL	Prairie ML	Prairie BL	Method of Resurfacing Track (Percent): Mech. Gang ML	Mech. Gang BL	Band Tamp. ML	Band Tamp. BL	Interval between Out-of-Face Resurfacing (Years): Under 10 MGT ML	Under 10 MGT BL	10-20 MGT ML	10-20 MGT BL	20-40 MGT ML	20-40 MGT BL	40-60 MGT ML	40-60 MGT BL
Alig.& Sou. (Yard only)	-	-	-	20	-	115- 90	-	-1	-	0	-	22	-	None	-	2-3	Steel Mill raw materials, ladles, etc.									0	0	0	100	0	0	-	90	-	10	Depends on traffic		-	-	-	-		
AT&SFe	90	59	60	45	136-119	110-112	9	-	Weld 48 Jtd 32	16-24	24	22	Slag	Rock Segs	4-5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	100	Nons	None	15	15-20	-	-	-	-	10	-
AOL	80	59-30	65	40-30	132-115	100- 70	0	0	12-14	6-10	24	24	Cr.Stone	Gravel	2½	2½							x			2	0	20	20	78	80	100	80	0	20	5	7	4	6	3	5	3	5
B&A	55	50	49	44	115-100	100- 70	0	0	B	B	21	21	Rock Gravel	Gravel	3-4	3-4					x				x	0	0	100	100	0	0	0	0	100	100	On section crew basis. No cyclic maintenance.							
B&M	70	40	45	30	131- 85	100- 72	0	0	B	B	23	20	Stone	Gravel	1½	3	x									25	25	75	75	0	0	100	75	0	25	No records available		-	-	-	-		
C. of G.	70	55	55	40	115	115- 80	0	0	24	16	24	22	Rock	Cinders Gravel Rock	2½	2½	31	9	2	8	20				30	17	17	72	72	11	11	100	100	0	0	4	6	4	-	4	-	4	-
CB&Q	79	45	50	35	129-112	112- 56	-1	0	28	Varies	24	22	Slag	Gravel Rock Shale	6	3	x	x						x	x	10	2	65	68	25	29	95	50	5	50	Generally 15 years in ML territory							
CMSP&P	90	70	60	45	132- 90	90- 65	0	0	16	16	24	24	Gravel	Gravel	2	2	30	17	10	3					49	13	18	79	76	8	6	85	60	15	40	6-10	12-16	-	-	-	-	-	-
D&O	80	59	60	40	140-110	132- 67	0	0	16-32	12-24	23	23	Gravel Slag Stone	Gravel Stone	3	3	29	51	2	2					16	20	30	30	30	50	40	95	80	5	20	3- 6	4-10	2-5	3-6	2-4	3-6	2-4	-
CNW	90	-	60	Varies	115	112- 60	-	0	24-32	8-12	23	23	Quart-zite	Sorseninge Gravel	4	4	x	x	x	x				x	x	-	-	10	20	90	80	100	50	0	50	Depends on traffic and subgrade conditions.							
Clinchfield	None	None	55	45	132-112	112- 85	0	0	28	28	24	24	Cr.Stone	Cr.Stone	2	2	15	70		0.7	1.5	10.5	1	1.3	-	90	80	10	20	0	0	100	100	0	0	-	-	5	6	3-5	-	-	-

SUMMARIES OF REPLIES TO QUESTIONNAIRE

Name of Railroad	Pass ML	Pass BL	Freight ML	Freight BL	Weight of Rail ML	Weight of Rail BL	Percent Welded or Frozen Jt. Const. ML	Percent Welded or Frozen Jt. Const. BL	No. of Anchors per Panel ML	No. of Anchors per Panel BL	No. Ties per Panel ML	No. Ties per Panel BL	Type Ballast Used ML	Type Ballast Used BL	Max. Raise (in) during Resurf'ing ML	Max. Raise (in) during Resurf'ing BL	Percent Predominate Type Traffic: Mdse	Coal	Ore	Oil	For. Prods.	Mine Prods.	Per-ish.	Agri.	Misc.	Terrain (Percent): Moun-taicous ML	Moun-taicous BL	Rolling ML	Rolling BL	Prairie ML	Prairie BL	Method of Resurfacing Track (Percent): Mech. ML	Mech. BL	Gang ML	Gang BL	Hand Tamp. ML	Hand Tamp. BL	Interval between Out-of-Face Resurfacing (Years): Under 10 MGT ML	Under 10 MGT BL	10-20 MGT ML	10-20 MGT BL	20-40 MGT ML	20-40 MGT BL	40-60 MGT ML	40-60 MGT BL
CPR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	100	Do not use machinery and no cycle		-					
DRGW	75	Varies	60	Varies	133-100	Varies	3	0	12-24	Varies	24	20	Slag	Gravel	6	4	x	x								70	90	0	0	30	10	100	0	100	0	100	As required								
DT&I	45	30	45	30	115-112	90-85	1	0	16	8	22	20	Crushed Limestone	Crushed Limestone	2	2	x	x						x		10	20	90	80	0	0	90	20	10	80	7	Indef.								
DM&IR	60	60-30	35-30	35-30	-	-	0.2	0	8-16	8-16	23	22	Cr.Gravel	Mine Tailings	2	2		100								0	0	100	100	0	0	95	95	5	5	7	10	5	8	-	-	-	-		
GTW	79	50	60	40	132-100	100-56	0	0	10-16	8	22-23	21-22	Cr.Rook Limestone	Cinders Gravel	2½	2	x	x			x			x		0	0	100	100	0	0	90	10	10	90	5	10	-	-	-	-	-	-		
IC	100	-	60	50	132-115	112	10.07	0	12	12	12.2	12.2	Slag	Stone	2	2	8.8	44.6	1.0	0.7	4.7		7.6		32.7	0	0	17.5	100	85.2	0	100	100	0	0	-	-	-	-	3-5	3-5	-	-		
L&N	70	40	50	35	132-100	100-70	0.1	0	16	12	24-22	22	Slag Stone	Slag Stone	1½-2	1½-2	x	x								30	30	60	60	10	10	80	50	20	50	4	7	3	7	-	-	-	-		
MeC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	100	100	-	On section force basis, no cyclic maint.						
Monon	75	-	55	40	130-100	100-90	3	0	12	-	24	-	Stone	Gravel	2½	4	70	20							10	0	0	44	20	56	80	90	50	10	50	-	10	8	-	-	-	-		
Mo.Pac. (Arkansas Div)	79	45	50	35	132	90	0.5	0	12-16	10	24	22	Stone	Cr.Gravel Stone	3	3	x							x		0	0	0	100	100	0	100	100	0	0	-	10	-	-	-	-	5	-		
NYC	85	60	60	50	127	127-80	1	0	16	Varies	24	24	Stone	Gravel	2	3	All types									5	5	95	95	0	0	100	100	0	0	2-6	4-10	2-6	4-10	2-6	4-10	2-6	4-10		
NYC&StL	70-65	-	60-55	45-35	132-110	110-90	0	0	24	8-16	24	22	Gravel Stone, Slag	Gravel Stone	2¼-4	2-2½	x	x	x				x			0	0	75	75	25	25	80	0	20	100	6	8	5	-	4	-	-	-		
N&W	78	-	78	30	132	131-130	1	0	24	16	24	24	Limestone	Limestone	2½-3	2½-3		x								50	90	35	5	15	5	100	100	0	0	6	7	5	6	4	-	4	-		
NP	75	55	55	45	132-100	100-72	7	0 Weld 54 Bolt 28	Bolt 20		23	21	Cr.Rook	Processed Gravel	2	0-2	x				x			x		10	-	50	-	40	-	100	100	0	0	-	-	8	15	-	-	-	-		

SUMMARIES OF REPLIES TO QUESTIONNAIRE

Name of Railroad	Maximum Speed Pass ML	Maximum Speed Pass BL	Maximum Speed Freight ML	Maximum Speed Freight BL	Weight of Rail ML	Weight of Rail BL	Percent Welded or Frozen Jt.Const. ML	Percent Welded or Frozen Jt.Const. BL	No.of Anchors per Panel ML	No.of Anchors per Panel BL	No.Ties per Panel ML	No.Ties per Panel BL	Type Ballast Used ML	Type Ballast Used BL	Max.Reise (in)during Resurf'ing ML	Max.Reise (in)during Resurf'ing BL	Percent Predominate Type Traffic Mdse	Coal	Ore	Oil	For. Prode.	Mine Prode.	Per-ish.	Agri.	Misc.	Terrain (Percent) Mountainous ML	Mountainous BL	Rolling ML	Rolling BL	Prairie ML	Prairie BL	Method of Resurfacing Track (Percent) Mech.Gang ML	Mech.Gang BL	Hand Tamp. ML	Hand Tamp. BL	Interval between Out-of-Face Resurfacing (Years) Under 10 MGT ML	Under 10 MGT BL	10-20 MGT ML	10-20 MGT BL	20-40 MGT ML	20-40 MGT BL	40-50 MGT ML	40-50 MGT BL
PRR	80	70	60	50	155-130	131-70	-1	0	8-10	-	22-24	20-22	Stone Slag Gravel	Stone,Slag Gravel Cinder	3	3-4		x	x							25	25	76	75	0	0	56	40	15	60	5	5	3	3	2	3	2	-
PRLE	70	50	60	30	132	115	-	-	16	10	24	20	Slag	Slag	4	3		x	x							-	-	-	-	0.3	1	96	95	5	6	-	-	-	5	3	-	-	-
RP&P	50	55	-	-	140-131	-	17.5	-	Weld AREA 16	-	24	-	Stone	-	1-1½	-	x	x						x		0	-	100	-	0	-	100	-	0	0	5	-	-	-	-	-	-	-
SP (T&NO)	75	None	60-60	25-40	136-113	112-75	2	0	10	4-8	24	22	Cr.Slag Cr.Dolomite	Crushed Limestone	4-6 1-2	4	x									0	0	70	75	30	25	100	100	0	0	14	14	12	14	8	-	8	-
Soo	65	45	55	30	100	80	3	0	28	10	24	22	Gravel	Gravel	2	2	34	5	26	2	19			16		0	0	25	10	75	90	100	15	0	86	10	20	-	-	-	-	-	-
TRRA	30	-	20	-	115-100	-	0	0	13	-	24	22	Trap Rock Mine Tailings	-	1-2	-	All types									0	0	0	0	100	0	100	-	0	-	No figures available				-	-	-	-
TAP	75	40	60	25	132-112	110-75	10	0	12-16	6-12	24	22	Cr.Stone	Screenings Gravel	1-2	2-4	x			x				x	x	10	0	66	50	25	50	100	50	0	50	6	-	5	-	-	-	-	-
UP	90	70	55	50	133-112	131-56	0.19	0	16	8	22	20	Cr.Rock	Gravel	2½-3	-	2	9	10	2	13	12		24	28	55	36	31	16	34	49	33	0	67	100	Varies considerably							
Veg.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	No information available							

(x) Indicates no percentage reported.
(-) Indicates information not furnished.

Report of Committee 27—Maintenance of Way Work Equipment

A. W. Munt, *Chairman,*
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Vice Chairman,
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G. M. Strachan
M. C. Taylor
T. H. Taylor
H. A. Thyng
S. E. Tracy
L. B. Waterman
F. E. Yockey
G. L. Zipperian
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
No report.

1 (a). Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment.
Progress report including recommended revisions ..... page 418

3. New developments in work equipment.
Final report, presented as information ..... page 423

4. Improvements to be made to existing work equipment.
Progress report, presented as information ..... page 427

5. Instructions for preventive maintenance of trucks.
Final report, presented as information ..... page 430

6. Equipment for loading, transporting, unloading and installing continuous welded rail, collaborating with the Special Committee on Continuous Welded Rail.
Final report, presented as information ..... page 442

7. Number of units of work equipment to be repaired by field repairmen.
Final report, presented as information ..... page 446

8. Fuel and lubrication trucks for use with mechanized gangs.
Final report, presented as information ..... page 448

9. Instructions for the care and safe operation of welding equipment.
   No report.
10. Four-cycle vs two-cycle gasoline engines used on small equipment.
    Final report, presented as information ..... page 455
11. System vs division shops for maintaining work equipment.
    No report.
12. Shop machinery and equipment needed for work equipment shops.
    Final report, presented as information ..... page 461

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
A. W. MUNT, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 1 (a)

Revision of Handbook of Instructions For Care and Operation of Maintenance of Way Equipment

S. E. Tracy (chairman, subcommittee), R. E. Berggren, L. E. Conner, J. W. Cummings, Haynie Hornbuckle, C. F. Lewis, J. W. Risk, F. E. Short.

Investigation discloses that since the revision and reprinting of the handbook in 1957 three additional types of units of work equipment have been developed and now have sufficient general distribution and use to justify the writing of instructions covering their care and operation.

Your committee therefore submits the following report with the recommendation that this material be included in the next revision of the handbook.

TIE BED SCARIFIER

DESCRIPTION: A self-propelled, four-wheel, on-track unit consisting of a power plant and a hydraulic system to provide propulsion, operation, and control of a turntable, and a three-section horizontal revolving drum equipped with renewable points.

APPROXIMATE WEIGHT: 5200 lb

MFG. RECOMMENDED SPEED:

Engine governor setting—No load 1900 rpm

TRENCH LENGTH:

Main drums	9 ft 1 in
Extensions	9 in and 15 in

HYDRAULIC SYSTEM:

Reservoir Capacity	27 gal
Pressure, Maximum	2000 psi

USE: To facilitate the installation of ties by scarifying the tie bed and removing a portion of the ballast to provide a tie bed of uniform depth at the proper position in the track.

CARE AND OPERATION:

General

3.26.35 Before starting the engine

a Open both gate valves, one on each side of hydraulic oil reservoir.

b Disengage clutch.

c Set hand brake.

3.26.36 Before traveling with machine

a Check vacuum pressure. (Brakes require 10 to 18 inches vacuum for proper operation.)

b See that digging drums are locked in the raised position.

c See that turntable ram is fully retracted and control valves are in proper position.

d Place two-speed gear in proper position.

e Place 4-way control valves in proper position.

3.26.37 While traveling

a Use low gear while working and when traveling short distances.

b Use high gear for traveling or as conditions require.

c Do not attempt to shift gears while machine is in motion.

3.26.38 Towing

a On machines equipped with two-speed gear, place in neutral position.

b Machines not so equipped shall not be moved in excess of 10 mph.

3.26.39 Before putting the digging mechanism in operation

a Place 4-way valve handle in left position.

b See that guards are in satisfactory condition and properly secured.

c See that the renewable digging teeth are properly mounted and secured in the revolving drum.

d See that there are no obstructions which will interfere with the free movement of the revolving drums.

e See that drive chains are in line with sprockets and in proper adjustment.

3.26.40 To scarify

a Lower revolving drum slowly into ballast until digging frame rests on stop blocks.

b Set and lock adjusting screws as necessary to obtain desired depth.

c Adjust valve controlling speed of descent to suit ballast conditions.

3.26.41 While scarifying

a Reverse control lever must not be moved while drums are revolving.

Hydraulic System (See Rules 4.10.1–4.10.16, inclusive)

3.26.42 Do not use hydraulic brake fluid in this hydraulic system.

3.26.43 Replace return line filter elements when filter pressure of 15 psi is indicated by gage mounted on top of filter case.

3.26.44 After using the emergency hand-operated pump see that valves are placed in proper position before attempting to use the power system.

3.26.45 Move control levers slowly to prevent sudden reaction which might result in damage to the machine.

COMBINATION TAMPER-JACK, TYPE 1

DESCRIPTION: A self-propelled, four-wheel, on-track unit consisting of power plant, three hydraulic systems, and an electric generator. The hydraulic system provides the power for the propelling, track raising,, clamping and tie nipping mechanisms, and the raising and lowering of the tamping heads. Each tamping head has two electric motors (4 tools) which operate outside the rail. A leveling device using standard cross level and spot board are incorporated in the design.

APPROXIMATE WEIGHT: 8000 lb

MFG. RECOMMENDED SPEEDS:

Engine	
Generator	2260 rpm
Vibratory Motors	4500 rpm
Travel, Maximum	25 mph

HYDRAULIC SYSTEMS, PRESSURES:

Jack Rams, Max	3500 psi
Travel, Max	700 psi
Workhead, Rail Clamps, Tie Tongs, and Nipper	700 psi, Max

GENERATOR VOLTAGE:

Tampers Operating In Air	150–160 v
No Load	160–170 v

ATTACHMENTS:

Various widths of tamping bars.

USE: To provide a mechanical means of raising the track in connection with spot or out-of-face surfacing operations and to tamp the tie at the point of lift.

CARE AND OPERATION:

General

3.17.20 The operator and others concerned in the operation of this machine shall be governed by the applicable instructions under

jacks, power track, hydraulic; and tie tamper, multitool, electric Types 1 and 2; and the rules which follow.

3.17.21 Before starting engine, see that over-center clutch is in neutral position.

Before Traveling

3.17.22 See that the tamping heads, rail clamps, and jack rams are locked in the raised position.

While In Operation

3.17.23 Operators and other concerned in the operation of this machine shall keep in the clear of the tamping heads and clamping mechanisms while machine is being operated.

3.17.24 Observe action of tamping blades and reverse direction of motor rotation if blades do not move toward the rail when penetrating the ballast section.

3.17.25 Generator and tamping motors must be operated at recommended rpm to prevent damage.

Towing

3.17.26 Place the transmission in neutral position if necessary to tow this unit.

Hydraulic Systems

3.17.27 Do not use hydraulic brake fluid.

3.17.28 A non-detergent light weight oil, SAE 10W or equal, is recommended for use in this hydraulic system.

ADJUSTMENTS:

3.17.29 Rail clamps are in proper adjustment when front wheels of the machine are raised ¼ in to ½ in above ball of rail when making a lift.

3.17.30 The sighting blocks are in proper adjustment for use with standard spot board when the top edge of the block is 12 in above the rail ball.

3.17.31 Unless otherwise instructed, adjust motor belts as necessary to provide 17 in space between tip of opposing tamping blades.

3.17.32 Unless otherwise instructed, adjust positioning belts to provide 9 in space between ball of rail and nearest edge of tamping blade.

3.17.33 Adjust motor limiting belt as required to prevent contact between tamping blade and base of rail when tamping head is at lowest point of travel.

3.17.34 Motor suspension belts are in proper adjustment when tension permits motor sag of about ⅜ in between belt supports.

3.17.35 All bolts must be kept tight, paying particular attention to tamping blade bolts.

3.17.36 Adjust tamper workhead stop (bumper) as necessary to prevent damage to workhead ram.

COMBINATION TAMPER-JACK, TYPE 2

DESCRIPTION: A self-propelled, four-wheel, on-track unit consisting of a power plant, a hydraulic system which provides the power for raising the track, and an off-center revolving drum type of vibrating mechanism which activates the tamping bars. The unit is equipped with an adjustable leveling device; and is also used in conjunction with a track surfacing wire. The former unit is propelled by a friction drive and the latter units are equipped with a transmission drive.

APPROXIMATE WEIGHT: 5900 lb

OPERATING SPEED:

Engine, Max 2800 rpm

HYDRAULIC SYSTEM:

Pressure, Max 3000 psi

ATTACHMENTS:

Various sizes of tamping bars.

USE: To provide a mechanical means of raising track and tamping jack ties in track surfacing operations.

CARE AND OPERATION:

General

3.17.40 The operator and others concerned in the performance of this machine shall be governed by the applicable instructions covering jacks, power track, hydraulic, in addition to the rules which follow:

While In Operation

3.17.41 The lever controlling the tamping head must be held down during the period of tamping to provide maximum effect.

3.17.42 The operator shall manipulate the control levers on the hydraulic jack as necessary to insure that the sighting rail will be the first to reach the desired height; then level the opposite rail as indicated by the leveling device.

Before Traveling

3.17.43 The operator shall perform the following before traveling, except while engaged in tamping.

a Release the vibrator drum drive clutch.

b Lock the rail clamps in the raised position.

c Lock the tamping head in the raised position.

d Lock the leveling device in the raised position.

e Remove the sighting gages, if necessary.

ADJUSTMENTS:

Rail Clamps

3.17.44 The rail clamps are in proper adjustment when there is a space of 1/8 in between rail and contact points.

Rail Clamp Hooks

3.17.45 Rail clamp hooks are in proper adjustment when they clear inside edge of bail of rail 1/8 in.

Vibrating Drum

3.17.46 Proper distance between the face of the shaft and the face of the weight bolt nut is 1/2 in to 15/16 in.

3.17.47 Increasing the space results in greater vibration. Adjust with special wrench so as to provide only enough vibration to produce satisfactory results.

Jack Spud Shoe

3.17.48 Set the jack spud shoe to suit the average tie spacing by moving the jack frame in the desired direction as necessary to permit tamping bars to enter the crib without interference.

Bevel Friction

3.17.49 Adjust friction drive as required to maintain 1/16 in clearance between each side of the cone and the face of reverse bevel friction.

Report on Assignment 3

New Developments in Work Equipment

F. H. McKenney (chairman, subcommittee), A. C. Danks, Jr., W. E. Kropp, Francis Martin, F. N. Snyder, M. M. Stansbury, R. S. Stephens, T. H. Taylor.

This is a final report, presented as information. Previous reports on this subject are to be found in the Proceedings, Vols. 45, 50, 52, 53, 54, 55, 56, 57, 58 and 59. The current report covers machines marketed since the last report. As is customary, it includes the major improvements and additions that have been made to existing machines since last year's report.

Track Surface Wire Indicator System

In the development of combination machines for jacking and tamping track a piece of new equipment has been devised for establishing the grade line and indicating the amount of lift at the jacking machine. The equipment consists of two carriages, held rigidly at fixed distances ahead and behind the tamping jack by metal tubing supported on two-wheel buggies, carrying two tightly drawn fine wires 125 ft long over the top of the jack. These correspond to the line of sight of the raising foreman. The tamping jack raises the track to the wire in the same manner it would raise to the line of sight of a foreman. The sections of the surfacing wire attachment are light in weight, and one man can handle any one of them, except the end carriages which two men can handle easily.

This has recently been modified to permit shortening the wire to 50 ft–30 ft ahead of the jack and 20 ft behind—where it is desired to spot track without making a raise. Observation of this operation shows that a very fine rail surface results. A multi-tool tamper follows the jack tamper, completing the spotting job.

Wire Line Indicator for Curves and Tangent

A modification of the above wire surfacing attachment is a wire lining attachment to accompany a power track liner. For this purpose a similar carriage and buggy arrangement, attached ahead and behind the track lining machine, carries a single tightly stretched wire 120 ft long just above rail level and at an arbitrary distance of about 8 in outside the rail so as to be in the clear of the equipment. A measuring device attached to a pointer shows the ordinate of curve at the liner. In operation the liner with the wire attachment is moved around a curve and ordinates recorded at each joint. These may be plotted on coordinate paper and a graphic solution made to equalize the in and out throws and produce a smooth curve. The liner is then rerun around the curve and lines track at joints, quarters, and centers, to the new selected ordinates. This device is equally useful in removing short kinks from tangent track. It will not remove long swings but will remove the short irregularities within the 120-ft length of line wire.

Radio-Controlled Track Surfacing System

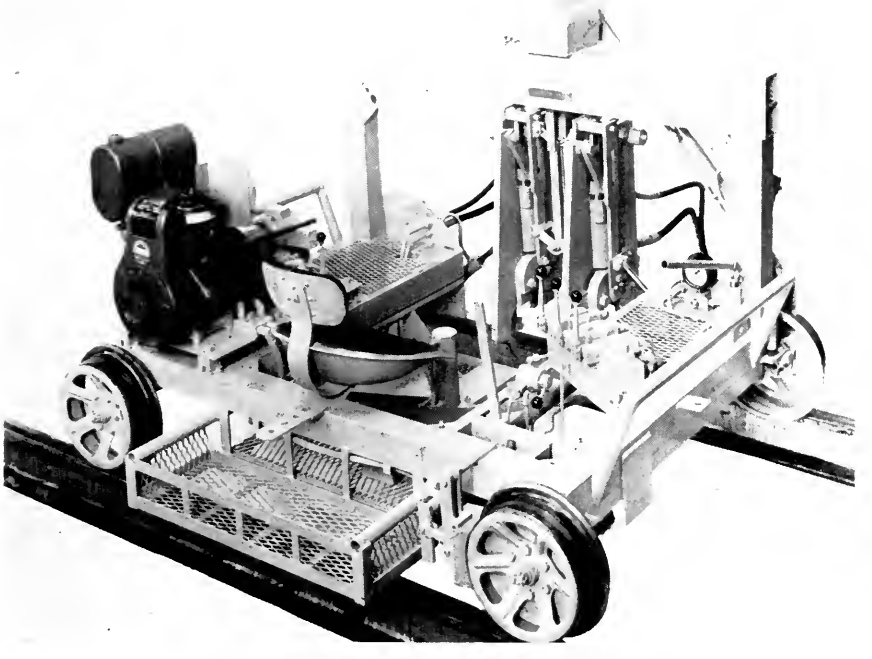
Another manufacturer is coming out with an optical device to be used with any power jack, jack tamper, or with hand jacks for establishing grade for raising track for surfacing. This consists of a radio-controlled spot board which can be moved along the track either backward or forward by remote control. It is used in the same manner

Radio-controlled spot board.

as the familiar spot board except that instead of being moved forward and set by hand, it is motor-operated by the man with the sighting telescope. The device consists of three parts: the battery-operated, motor-driven spot board on a carriage; a middle self-leveling sighting bar at the point the jack is placed; and a six-power surfacing telescope, mounted on a carriage with the radio control apparatus for push-button operation of the spot board. It is said the board can be controlled for distances of several hundred feet.

Rail Anchor Applicator Machines

Several manufacturers are now developing machines for applying rail anchors. All but one of the machines are designed to apply singly only one kind or type of anchor. One machine has been developed which applies any one of several types of anchors



Rail anchor applicator.

and applies them two at a time, box anchoring the tie while holding the anchors tight against the tie face. All of these machines are still going through the development stage with frequent changes. One machine is operated by compressed air and others by hydraulic power. One has a mechanical hammer which is quite effective in applying drive-on anchors.

Bridge Spray Machine

A new adaptation of a rubber-tired, two-wheel-mounted 125-cu-ft air compressor

is a machine for spraying heavy protective coatings on bridges, track ties, etc. The basic unit is the rubber-tired compressor which has been fitted with a frame and retractable flanged wheels for operating on the track. The frame provides space for carrying six 55-gal drums of coating material. It can operate up to eight standard paint guns. It is provided with a thermostatic-controlled heating system for maintaining proper temperature of the spray material. The machine is self propelled on the rail and with the flanged wheels retracted, may be towed on the highway on the rubber-tired wheels.

Multi-Tool Tampers

Another European multi-tool tamper has been introduced in this country. It differs from other machines in that it is hydraulically driven and controlled. It incorporates push-button operation and is said to have pressure adjustments for the 16 tools, some of which are automatic in action.

A Canadian built multi-unit machine has just been introduced which is equipped as a multi-tool tamper of the electric vibrator type, a power jack and track lining

Multi-unit tamper with crawler set off and hydraulic tail rack.

device said to be able to line 2000 ft per hr, a spike puller and spike driver (with proper conversion unit), a tie-pulling and replacing unit, and a power drill and wrench attachment. The tamping unit carries a hydraulically operated tail rack on which three of the auxiliary units may be loaded and carried.

Rubber-Tired Cranes

Several of the manufacturers of rubber-tired cranes are now adding flanged wheels to permit operation on the rails as well as off track. This is a trend in new developments to make the equipment more flexible and simplify its movement when used around or upon tracks.

Set-Off Equipment

While not in itself a piece of work equipment, several manufacturers are now producing lightweight, adjustable, metal set-offs for machines up to 8 tons in weight. These set-offs have adjustable legs to fit the ground and can be carried along and quickly erected where needed. Several of these have recently been marketed. It is claimed to save considerable machine travel time.

Report on Assignment 4

Improvements to Be Made to Existing Work Equipment

G. L. Zipperian (chairman, subcommittee), R. M. Baldock, P. H. Cote, Haynie Hornbuckle, C. F. Montague, H. C. Nordstrom, G. M. Strachan, L. B. Waterman, F. E. Yockey.

A progress report, submitted as information, this is a continuation of the progress reports submitted by this committee and found in Vol. 53, 1952, page 396; Vol. 54, 1953, page 666; Vol. 55, 1954, page 502; Vol. 56, 1955, page 525; Vol. 57, 1956, page 488, and Vol. 58, 1957, page 585. It covers changes in work equipment that this committee has found to be practical and desirable.

Diesel Pile Hammer

This is a self-contained, single-acting pile hammer using the same principle as a diesel engine.

Suggested improvements to this machine:

1. Install a lock-out device making it impossible to latch the starting mechanism when the hammer is actually driving a pile.

2. Improve the material in the studs or redesign method of bolting the fuel pump mounting bracket and the starting device cover to avoid stud breakage.

Tie Handler

This is a three-wheel, track-mounted self-propelled machine for applying ties in track.

Suggested improvements to this machine:

1. It should have a boom that can be swung 180 deg instead of a stationary boom.

2. The machine should be mounted on four 14-in wheels and two axles of push-car design and propelled by two wheels instead of one. The present machine cannot be towed or self-propelled any distance and has difficulty in moving through frogs, switches and highway crossings.

Tie Remover

This is a three-wheel, track-mounted machine with hydraulic ram for removing ties from the track.

Suggested improvements to this machine:

1. Provide a mechanical rail clamp to be applied by the operator instead of the chains and hooks to permit one-man operation.

Track Broom

This is a four-wheel, track-mounted, self-propelled machine for sweeping the excess ballast from the tops of the ties between and outside the rails and distributing it on the shoulder.

Suggested improvements to this machine:

1. All sprockets should be of the draw-in bushing type with keyways instead of being loose on the shafts and held with keys and set screws.

2. The hydraulic system should be redesigned in an effort to eliminate transmission failures.

3. Replace one-shot lubricating system with pressure gun fittings for grease. The one-shot oil lines are too small and fragile. The operators tend to ignore the lubrication entirely in case of broken or plugged oil lines.

4. Wheels and hubs should be designed to carry the load on the hubs instead of the bolts.

5. The machine has insufficient side clearance to clear all switches and has close clearance between the conveyor belt frame and crossings.

Ballast Regulator

This is a self-propelled, track-mounted, four-wheel-drive machine for equalizing ballast and shaping shoulders.

Suggested improvements to this machine:

1. Sprockets are loose on the axles and shafts, and should be provided with a means of being tightened, such as a draw-in tapered bushing.

2. Recommend using split-plate sprockets on axles to eliminate removal of axle when sprockets become worn in the field.

3. Replace one-shot lubricating system with fittings for a grease gun. Present system oil lines are too small and fragile. In case of broken oil lines and failure, operators tend to ignore lubrication entirely.

4. Wheels and hubs should be designed to carry the load on the hubs instead of the bolts.

5. On the slider box for adjusting side wings up and down by means of long adjusting bolts, threads are being stripped on the bolt and in the hole. These components should be redesigned to provide better wear.

6. The horizontal slider boxes are equipped with roller bearings which are exposed to dust and dirt, and are small and easily broken. Steel rollers with bronze bushings are recommended.

Combination Tamper-Jack

This is a four-wheel, track-mounted, self-propelled machine used to raise track hydraulically and to tamp sufficient ties to eliminate the use of leveling jacks in surfacing operations.

Suggested improvements to this machine:

1. The machine vibrates excessively, causing the bubble in the cross-level to fluctuate making accurate reading difficult.

2. The power tamping jack should have sufficient speed and power to pick up and tamp the desired number of ties ahead of the multiple-tool tampers. These machines

should be speeded up and should provide greater tamping action to accurately hold the surfaced track without settling until tamping can be completed.

Track Surfacing Machine

This is a mechanical device with track-wheel-mounted bogies and two steel reference wires. It is propelled by and works in conjunction with a combination tamper-jack.

Suggested improvements to this machine:

1. Further improvements should be made to incorporate a means of correcting the track surface to a given elevation, making it possible to take out sags and other surface defects in one operation. At present the device makes corrections proportionate to a one-fifth ratio of the existing track surface.

Tie Tamper—Multi-Tool, Mechanical, Vibratory, Impact

This is a four-wheel, track-mounted, self-propelled machine, mechanical vibratory type, with tamping bars that are closed by a clutch-operated lead screw.

Suggested improvements to this machine:

1. Equipped with four-wheel instead of two-wheel brakes.
2. Clutch shifter fork for tamping bar closure screws should be reinforced to prevent breakage.
3. Tamping chassis crosshead guides should be redesigned to prevent shearing of bolts.

Tie Tamper—Multi-Tool, Mechanical, Vibratory Impact

This is a four-wheel, track-mounted machine, self-propelled, mechanical vibratory type, with a belt-driven, revolving, adjustable, off-balance weight which transfers vibration to the two splitheads with eight tamping bars on each head.

Suggested improvements to this machine:

1. Extend crankshaft of gasoline engine and apply outboard bearing to prevent breakage.
2. Considerable difficulty is experienced with this machine due to the length of the V belts driving the revolving weights. The belts flip over in the grooves and wear is excessive, causing frequent renewal of complete belt sets. Should be redesigned to shorten centers between pulleys.

Track Liner

This is a four-wheel, track-mounted, manually propelled machine with a hydraulic ram, the cylinder for which moves through an arc to reverse the lining action as needed.

Suggested improvements to this machine:

1. Provide a method of locking the cylinder in an upright position to avoid shifting of the cylinder when setting off.

Multiple Spike Driver

This is a four-wheel, track-mounted, self-propelled machine with air-operated spike-driving guns, two for each tie plate, capable of driving spikes simultaneously or separately.

Suggested improvements to this machine:

1. Lifting bail assemblies should be provided with bronze bushings and suitable lubricating fittings to provide a means of readily making repairs when parts become worn.

2. Stop plate for gun depth adjustment screw is not strong enough to resist the shock when the stop block strikes the plate, causing it to break or bend. Should be reinforced.

3. This machine should be equipped with a self-setting spike mechanism to eliminate the need of hand setting.

4. Provide an automatic valve to prevent the operator from placing it in motion while the guns are in operation driving spikes.

5. Provide a mechanical brake for parking and emergency.

Report on Assignment 5

Instructions for Preventive Maintenance of Trucks

E. H. Fisher (chairman, subcommittee), T. S. Bean, I.M. Boone, R. E. Buss, W. T. Hammond, S. H. Knight, W. F. Kohl, J. E. Reynolds, G. M. Strachan.

This is a final report, submitted as information.

Many preventive maintenance programs, control systems, and driver instruction methods are currently in use throughout the North American continent. They are employed in small, as well as large truck fleets, where efforts are being made to increase efficiency and improve the economy of operations. Needless to say, such systems vary from one location to another. This may be caused by one or many factors, such as conditions of operation, company policy, labor restrictions and a host of others.

First and foremost, proper operation of a vehicle is essential to maintaining high vehicle availability at minimum cost. Therefore, one of the first steps should be the careful selection and training of truck drivers. Failure at this point can easily result in unnecessary maintenance expense, even if repair facilities are ideal.

After the proper selection of an operator, the man should be provided with a vehicle that is clean and in sound operating condition. He should then be induced to take pride in *his* unit. A suggested routine for developing driver assistance in the preventive maintenance program is outlined hereunder:

Driver Instructions Before and After Starting the Engine

a. See that horn and lighting system, including stop light, are working properly.
b. Make certain that license plates are affixed to the truck and are clean.
c. Check steering as soon as the vehicle is moving by turning the steering wheel in both directions.
d. Check brakes by making an application as soon as the vehicle is in motion.
e. See that engine is performing properly.
f. Check to see if all tires look properly inflated. Check the pressure at least once a week.
g. Check to see that windshield wipers are working properly.
h. Cab glass should be clean to insure safe driving visibility.
i. Clean and adjust rear-view mirrors to the proper position.
j. Allow engine to warm up before applying load.

Before Starting Engine

a. Check the water level in the radiator.
b. Check fuel supply and see that tank is properly capped.
c. Check the engine oil level.
d. Place gear shifting lever in neutral.
e. De-clutch while starting the engine.
f. Check water level in battery when fueling vehicle.

While Vehicle Is in Operation

Check the dashboard instruments frequently to see:
a. That oil pressure is normal.
b. That ammeter charging rate is normal.
c. That the speedometer is working.
d. That the heat indicator reading is normal.

Driver Training

Competent drivers are essential to economic operations. Therefore, careful consideration should be given to the development of correct driving habits. This means that a training program, together with a regular follow-up, is essential in the war against mounting costs. Many automotive manufacturers and some suppliers will be glad to assist in the preparation of a course to fit your particular situation.

Driver's Report

The reduction in costly road failures and breakdowns can be materially assisted if the operator has a means of reporting defects. Any report used should be simple. Remember your operator is a vehicle driver, not a clerk. The report can be made daily, or only when there is something abnormal to report. Repairs should be carried out as soon as possible after the report has been made. A sample report presently being used is included in this report as Exhibit "A".

Preventive Maintenance

"Preventive maintenance" means exactly what the words denote—preventing maintenance. To do this requires vehicle inspections at *regular* intervals and repairing components before they fail in actual service. It is worthwhile to remember that a vehicle only earns its keep when it is working. Downtime means repair expense plus lost revenue.

A typical inspection cycle will now be described. However, it should be pointed out that its application must be tailored to actual service requirements. Naturally, an inspection cycle for ideal operating conditions will not be the same as one designed for extremely adverse operations. Individual judgment is required in each case. Once the cycle has been decided upon, it should be rigidly adhered to for optimum results, until such time as experience indicates a need for modification.

In Exhibits "B", "C", and "D" included herein it will be noted that the inspection intervals are spaced at 2,500 miles (Class A Inspection), 5,000 miles (Class B Inspection), and 10,000 miles (Class C Inspection), respectively. The estimated times required to carry out such inspections are 1 hr or less, 2 hr or less and 4 hr, in the same order.

As an inspection is made, the work to be done is noted in the right-hand column, and the definition of the inspection terms appears at the top portion of the report.

The inspection reports when completed are reviewed by a supervisor who arranges for the repairs to be made, based upon the schedule set up for this purpose. If, for instance, the repairs are extensive, he may decide, in the case of an old vehicle, that the unit should be scrapped, or minimum repairs made until replacement is procured. He, therefore, would take the necessary action along this line.

Another system employs an inspection guide to be used when vehicles are in the garage for lubrication. A further A & B guide is used when scheduled preventive maintenance inspections are made. An inspection defect report used in conjunction with the lubricating and A & B inspection guides is placed under a material, such as celluloid or glass, and is used by the mechanic doing the work. Samples are shown in Exhibits "E", "F", and "G". The inspection defect report is used for either greasing and/or A & B inspections. The mechanic makes notations of defects for the headings located in the left-hand column of the inspection and defect report. Work resulting from the lubrication inspection is usually done immediately, if of a minor nature. The required work from A & B inspections is generally done by a mechanic other than the one performing the inspection.

The period between greasings will naturally depend upon the severity of operations. A suggested time interval for starting a system, similar to those described in the foregoing, would be 1000 miles or 2 months for summer and 500 miles or 1 month for winter operations, whichever is first.

A suggested interval for A & B inspections for high-mileage vehicles is 4000 miles, with two A inspections between each B inspection. For low-mileage vehicles, under 6000 miles per year, for example, one B inspection per year is all that is required. During the winter months only the greasing is done at the 500-mile intervals. Estimated time for inspections is 3 hr for an A and 5 hr for a B inspection.

Lubrication

Trucks should be lubricated as recommended by the manufacturers. For special operating and weather conditions your oil supplier should be consulted. Insofar as practical, lubrication should be scheduled during inspections; otherwise it should be done at regular intervals. Do not overlook the oil filter. The life of your truck depends on proper lubrication.

Tires

For information concerning rotating tires, balancing and front-end alinement, overloading, hitting holes and curbs, and other maintenance problems, consult your tire dealer.

Field Inspections of Motor Trucks

If facilities and skilled personnel are readily available, either through private garages or company-owned establishments, inspections and lubrications should be performed at such centers. This method provides a means of more efficient control over the maintenance dollar. In the absence of such maintenance centers, field inspections could be carried out by a mechanical supervisor, using a form similar to Exhibit "H". Any work that could not be done by a mechanic in the field could be carried out by a local garage.

Some companies have found it advantageous to have a non-schedule mechanical supervisor perform the inspection in local garages, assisted by a mechanic. Necessary

repairs are authorized by the supervisor and carried out by the mechanic in the privately owned garage. This method provides a measure of control over work that has to be done at points where company-owned facilities are not available.

For further information, and as a matter of interest, see pages 11 to 20, Section 2—Internal Combustion Engines, and pages 95 to 99, Trucks—Automotive, of the AREA Handbook of Instructions for Care and Operation of Maintenance of Way Equipment. Also see pages 505 to 507, Vol. 55, and page 536, Vol. 56 of the AREA Proceedings.

Exhibit "A"

Department _____ Place _____ Date _____

Motor Vehicle No._____ Route No._____

Speedometer Reading-out_____ In_____ Mileage_____

Gasoline Supplied _____Gals. Oil Supplied_____Qts.

Mechanical or Other
Repairs necessary _____

_____

_____

Time out_____Time in_____ Signature_____
Motorman

Give details of
work performed_____Date_____

_____

_____

_____

_____

_____

Signature_____

Exhibit "B"

Motor Vehicle Inspection Report (Trucks & Buses)

Class "A" Inspection
(At 2500 mile intervals)

Truck No._____ Date_____ Odometer Rdg._____ Driver_____

Definition of terms: L = Light or visual checkup
A = Adjust
T = Test

No.	Check	Item		Work to be done
1		Front end, Wheel Align., Steering	L	
2		Fire extinguisher	L	
3		Flares	L	
4		Instrument panel	L	
5		Windshield wiper	LT	
6		Windshield glass	L	
7		Brakes	LAT	
8		Clutch	T	
9		Cooling & heating system	L	
10		Electrical system	LT	
11		Electrical system - lights	LT	
12		Engine	L	
13		Air Compressor	LT	
14		Drive shaft	L	
15		Wheels, rims, etc.	L	
16		Marker Lights & turn signals	L	
17		Other (list below)		

Work performed by:_____

Exhibit "C"

Motor Vehicle Inspection Report (Trucks & Buses)

Class "B" Inspection
(At 5000 mile intervals)

Truck No._____ Date _____ Odometer Rdg._____Driver_____

Definition of terms: L = Light or visual checkup
A = Adjust
T = Test

No.	Check	Item		Work to be done
1		Front end, Wheel Align., Steering	L	
2		Fire extinguisher	L	
3		Flares	L	
4		Marker lights & turn signals	L	
5		Instrument panel	L	
6		Windshield wiper	L	
7		Windshield glass	L	
8		Brakes - adjust travel	A	
9		" check pressure	LT	
10		" check linkage	A	
11		Clutch	T	
12		Cooling & heating system	L	
13		Electrical system	L	
14		Lights & Focus	LT	
15		Wiring	L	
16		Coil	L	
17		Condenser	L	
18		Generator Drive	L	
19		Distributor points	L	
20		Horn	L	
21		Fuel & exhaust systems	L	
22		Crankcase air breather	L	
23		Fuel pump	LT	
24		Carburetor	LA	
25		Fuel lines	L	
26		Tail pipe	L	
27		Engine	L	
28		Valves	L	
29		Timing	L	
30		Sparkplugs	LT	
31		Leaks	L	
32		Air compressor	LT	
33		Springs, clips, bolts, etc.	L	
34		Wheels, rims, etc.	L	
35		Cab, body, etc.	L	
36		Other (list below)		

Work performed by_____

EXHIBIT "D"

Motor Vehicle Inspection Report (Trucks & Buses)

Class "C" Inspection
(At 10,000 mile intervals)

Truck No._____ Date _____ Odometer Rdg._____ Driver _____

Definition of terms: L = Light or visual checkup
A = Adjust
H = Heavy or physical inspection or repair
T = Test

No.	Check	Item		Work to be done
1		Front end, Wheel Align., Steering	H	
2		Fire extinguisher	L	
3		Flares	L	
4		Marker lights & turn signals	L	
5		Instrument panel	L	
6		Windshield wipers	L	
7		Windshield glass	L	
8		Brakes - pedal travel	H	
9		" Line pressure	T	
10		" Slack adjusters	AT	
11		" Handbrake & linkage	AT	
12		" Master cylinder fluid	H	
13		" Oil booster cylinder	L	
14		" Air, oil or vacuum lines	LT	
15		Clutch	H	
16		Clutch pedal	TA	
17		Cooling & heating system	H	
18		Radiator & hose connections	H	
19		Radiator tie rods	H	
20		Water pump complete	H	
21		Electrical system	H	
22		Lights - focus & wiring	H	
23		Ignition wiring	H	
24		Generator & drive & cables	H	
25		Starting motor & cables	H	
26		Distributor & points	H	
27		Horn, including wiring	H	
28		Fuel & exhaust systems	H	
29		Crankcase air breather	H	
30		Fuel pump	H	
31		Carburetor	H	
32		Fuel lines	T	
33		Gastank	H	
34		Tail pipe	H	
35		Engine - Crankcase	L	
36		" Belting	H	
37		" Cylinder head bolts	T	
38		" Valve setting	T	
39		" Spark plugs	H	
40		" Compression test	H	

	1	2	3	4	5	6	7	8
Dry								
Wet								

41		Air Compressor	H	
42		Springs, clips, bolts, etc.	H	
43		Steering assembly	H	
44		Transmission	H	
45		Drive shaft & rear axle	H	
46		Under chassis	H	
47		Body & cab	H	
48		Wheels, rims, bearings, etc.	H	
49		Other (list on reverse side)		

Work performed by _____

Exhibit "E"

INSPECTION GUIDE TO BE FOLLOWED WHEN LUBRICATING VEHICLES

Engine	1. Check engine running condition 2. Check for oil leaks 3. Check oil filters for leaks
Cooling System	1. Check cooling system for leaks 2. Check fan belt 3. During winter months, check and test anti-freeze
Air Vacuum System	1. Check operation of booster 2. Check windshield wipers
Electrical & Wiring	1. Check all lights 2. Check horn 3. Check heater 4. Check charging rate of generator 5. Clean, check and fill battery with distilled water
Chassis	1. Check muffler and tailpipe
Steering	1. Check all component parts of steering
Front Axle	1. Check kingpins
Rear Axle	1. Check differential breather 2. Check axle flange bolts
Clutch & Trans.	1. Check clutch pedal travel 2. Check transmission for leaks
Diff. & Driveshaft	1. Check universal joints for wear 2. Check differential for leaks
Springs & Shocks	1. Check springs and component parts 2. Check shock absorbers and component parts
Brakes	1. Check brake pedal travel 2. Check and fill master cylinder 3. Check braking system for visible leaks
Body and Cab Assembly	1. Report body condition
Painting	1. Report condition of paint
Tires	1. Check tires for unusual wear 2. Remove foreign objects imbedded in tires 3. Inflate tire to proper pressure 4. Report any tires with scuffed walls or tires due for retreading

Exhibit "F"

PREVENTIVE MAINTENANCE A & B INSPECTION GUIDE - MOTOR TRUCK & TRACTOR

ENGINE			
1.	A&B	Engine Oil	Inspect engine oil for water and fuel dilution and contamination. Change oil and filter.
2.	B	Cylinder Head	Inspect for evidence of coolant loss. Adjust valve lash. Tighten cylinder head bolts to torque specifications with torque wrench. Inspect to see that proper oil flow is taking place. Replace valve cover, use new gasket.
3.	A&B	Engine	Inspect for external oil leaks. Examine outside oil and fuel lines for chaffing and kinks.
4.	A&B	Fuel Filters	Clean all - clean fuel pump screen and bowl. Replace gasket.
5.	B	Fuel Pump	Test fuel pump for proper pressure and capacity.
6.	A&B	Spark Plugs	Remove, inspect, clean and gap. Replace if necessary.
7.	A&B	Distributor	Inspect points, change if necessary. Replace dist. if necessary Check rotor and caps for cracks. Grease cam. Check advance mechanism. Inspect wiring.
8.	A&B	Manifolds & Heat Riser	Tighten nuts. Inspect for leaks. Test operation of valve.
9.	B	Engine Supports	Inspect condition of insulators, tighten if necessary.
10.	A&B	Carburetor	Remove and clean air cleaner. Tighten carb. flange nuts. Inspect choke. Service and replace air cleaner. Check operation of carb., and adjust if necessary.
11.	A&B	Ignition Timing	Set timing with light. Adjust carb. with vacuum gauge. Check exhaust with gas analyser.
12.	A&B	Crankcase Breather Air Cleaner	- Clean and service. Remove and clean crankcase ventilator valve (B only)
COOLING			
1.	A&B	Radiator Core	Inspect for leaks. Inspect mounting. RAD.-Examine coolant level - add water if level is low or tag steering wheel if level is low and anti-freeze is used. RAD. & HEATER HOSES & CONN. - Inspect for leaks, cracks and deterioration. Tighten if necessary.
2.	A&B	Water Pump	Inspect for leaks. Inspect condition of bolts. WATER PUMP PULLEY- Loosen belt and check pulley for looseness.
AIR VACUUM SYSTEM			
1.	B	Air Compressor	Tighten mounts - adjust belts if necessary.
2.	A&B'		Clean and service compressor air cleaner and governor air cleaner.
3.	B	Booster	Inspect and oil booster. Clean and service air cleaner.
4.	A&B		Air tanks - drain. Windshield wipers - check for operation and inspect condition of blades.
ELECTRICAL & WIRING			
1.	A&B	Lights	Test all lights. Inspect lenses. Check aim of headlights.
2.	A&B	Battery	Take hydrometer reading of each cell, to ensure each cell is in charged condition. Fill with distilled water if necessary. Remove battery cables. Clean terminals, re-install cables and coat with petroleum jelly.
3.	B	Starter & Generator	- Inspect commutator and brushes. Tighten connections. Generator air cleaner - clean and re-oil. Do starter load test.
4.	A&B	Voltage Regulator	- Test. Adjust if necessary. Check charging circuit voltage drop.
CHASSIS			
1.	B	Frame & Brackets	Inspect for loose or broken members. Check security of front and rear bumpers.
2.	A&B	Muffler	Inspection condition of muffler, tail pipe, exhaust pipe & brackets.
STEERING			
1.	A&B	Steering Gear Housing	- Tighten steering gear housing bolts and inspect for leaks. Inspect all component parts of steering for wear and looseness. Front Wheel Bearings - inspect for bearing looseness. Check front and rear wheels for evidence of lubricant loss.
2.	A&B	Wheel Alignment	- Adjust toe-in. Before adj._____ after adj._____
FRONT AXLE			
1.	A&B	King Pins	Inspect for looseness. Tighten draw keys if necessary
REAR AXLE			
1	A&B		Tighten axle flange studs. See that rear axle breather exterior is free from dirt.
CLUTCH & TRANS. (MANUAL OR AUTO.)			
1.	A&B		Test operation of clutch and adjust to specification if necessary. CLUTCH & GEARSHIFT LINKAGES - Examine linkages for any abnormal condition.
2.	A&B	TRANS. (S)	Inspect for leaks. Tighten rear bearing retainer cap screws.
3.	B		If equipped with automatic transmission, make stall test.

Exhibit "F" (Contd.)

DIFF. & DRIVESHAFT

1. A&B — Inspect driveshaft centre bearings and brackets, universal joints and flanges. Inspect pinion bearing for looseness.
2. A&B Differential Housing - Inspect for lubricant leakage around differential housig and pinion oil seal. Tighten.

SHOCK ABSORBERS & SUSPENSIONS

1. A&B — Check shock absorbers for leaks, test operation.
2. A&B — Tighten spring U bolts, front and rear.
3. A&B — Inspect spring shackles for wear. Inspect for breakage, weakness or misalignment of springs.

BRAKES

1. A&B Master Cylinder — Examine fluid level and correct if necessary
2. A&B Brake Mechanism — Inspect hoses, lines, chambers, etc., for leaks - tighten connections. Examine cross shaft cables, linkage, slack adjuster, etc. for abnormal wear. Inspect for oil and grease on drive line type parking brake. Brakes - adjust, service, front and rear and parking brakes. Check brakes for leaks, inspect brake pedal free travel and report.

BODY AND CAB ASSEMBLY (INCL. PAINT.)

1. A&B Door Locks, Hinges & Window Regulators - Inspect for wear and proper operation, etc., lubricate. STRIKER PLATES & DOVETAILS - Inspect for wear and proper operation. SAFETY DEVICES - Is vehicle equipped with the following :- turn signals,_____, first aid kit_____, reflectors_____, jack_____, clearance lights_____flares_____, fire extinguisher_____, mirrors_____, CAB INTERIOR - Check floor boards, mats, seat cushions, door panels, cab light, rear vision glass, head lining, etc. PAINT & SHEET METAL - Inspect condition of cab, fenders, grill, hood, etc. CAB HOLD DOWN BOLTS- Tighten as necessary. BODY - Tighten U bolts, check condition of metal and wood. Check tarpaulin or canvas covering.

TIRES

1. A&B — Inspect for unusual wear. Remove stones and other objects imbedded in tires. Check tire air pressure and inflate to proper pressure.

NOTE — Report any other defects found not mentioned in the preceding paragraphs that require repairs before the next 6,000 mile inspection.

ROAD TEST — Vehicles should be road tested before and after inspection and the following is a guide for checks to be made :

Clutch - Check for slipping and grabbing.
Instruments and accessories - inspect operation.
Brakes - Test operation of service brakes and parking brake.
Booster - Before moving vehicle, make booster operating test.
Check transmission for shifting operation
Check speedometer, hubdometer and odometer.
Power train - report on operation.
Check engine for detonation
Check engine operating temperature and record.
Check air compressor governor operation for cutting in and out at proper los. P.S.I.
Check horn.

Exhibit "G"

G - A - B - INSPECTION DEFECT REPORT DATE :

VEHICLE NO. MILEAGE W/O NO.

COMPRESSION TEST (A & B only)	CYL.	1	2	3	4	5	6	7	8
	DRY								
	OIL ADDED								

OIL PRESSURE (HOT)
IDLE _____ MAXIMUM _____

ROAD TESTED BY (A & B only)
IF NECESSARY

CLOCK #

DEFECTS REQUIRING REPAIRS BEFORE 6,000 MILES OR A &B INSPECTION

ENGINE		
COOLING		
AIR VACUUM SYSTEM		
ELECTRICAL & WIRING		
CHASSIS		
STEERING	(A & B) TOE-IN =	
FRONT AXLE		

REAR AXLE		CLOCK #
CLUTCH & TRANS. (MANUAL-AUTO)	SHIFTING SPEED: UP_____ DOWN _____	
DIFF & DRIVE SHAFT		
SHOCKS SUSPENSIONS		
BRAKES		
BODY ASSY. CAB ASSY. (INCL. PAINT)		
TIRES		

INSPECTED BY: _____ SUPERVISOR _____

Exhibit "H"

VEHICLE NO	MAKE	YEAR	MODEL	SERIAL NO	MOTOR NO	BODY TYPE	LOCATION

ROAD TEST
CHECK OPERATION AND REPORT ON

BRAKES	BOOSTER OR AIR PRESSURE	ACCUMULATED MILEAGE	DATE
STEERING	POWER TRAIN	MONTH & YR FULLY DEPRECIATED	OIL CONS PREV 3 MOS M.P.A.G.
OIL PRESSURE WITH HOT ENGINE IDLE MAXIMUM		GENERAL APPEARANCE	
INSTRUMENTS & ACCESSORIES			

COMPRESSION TEST TEST & RECORD ON EACH CYLINDER	CYL	1	2	3	4	5	6	7	8
	DRY								
	OIL ADDED								

GRADE OF OIL OR GREASE USED IN

ENGINE	TRANSMISSION	DIFFERENTIAL
SAE	SAE	SAE

REPAIRS REQUIRED	ESTIMATED REPAIR COST	REMARKS & RECOMMENDATIONS (IF LISTED EXPENDITURES NOT RECOMMENDED—EXPLAIN)
ENGINE		
COOLING SYSTEM		
AIR-VACUUM SYSTEM		
ELECTRICAL & WIRING		
CHASSIS		
STEERING		
FRONT AXLE		
REAR AXLE		
CLUTCH & TRANS MANUAL OR AUTO		
DIFF & DRIVE SHAFT		
SPRING & SHOCKS		
BRAKES		
BODY AND CAB ASSEMBLY		
PAINTING		
MISCELLANEOUS		
SUB TOTAL—REPAIRS		

TIRES *SHOW NEW TIRE COST LESS PRESENT VALUE	*AMOUNT	
FRONT RIGHT ____ % WORN		
FRONT LEFT ____ % WORN		
REAR LEFT OUTSIDE ____ % WORN		
REAR LEFT INSIDE ____ % WORN		
REAR RIGHT INSIDE ____ % WORN		
REAR RIGHT OUTSIDE ____ % WORN		
SUB TOTAL—TIRES		
GRAND TOTAL		LIFE EXPECTANCY ____ YEARS IF REPAIRS LISTED CARRIED OUT

DATE

SIGNATURE & TITLE

Report on Assignment 6

Equipment for Loading, Transporting, Unloading and Installing Continuous Welded Rail

Collaborating with the Special Committee on Continuous Welded Rail

J. H. Brown (chairman, subcommittee), R. W. Bailey, O. C. Benson, G. R. Collier, J. O. Elliott, F. L. Etchison, J. S. Fluke, C. F. Lewis, Francis Martin, N. E. Smith.

This is a final report, submitted as information.

Subsequent to World War II there has been a definite trend toward the greater use of continuous welded rail by the American railroads. Because of this experience, various methods of loading, transporting, unloading and installing continuous welded rail heretofore deemed impractical have been proved successful. It is the purpose of this report to describe the most widely used and accepted practices of handling continuous welded rail.

At present, from 17 to 37 standard-length rails are being welded and layed. The rail sections range from new 115 lb to 155 lb, with blank ends and without end heat treatment. In some instances railroads have justified the welding of lighter weight relay rail. This procedure requires transporting rails in lengths up to approximately 1500 ft.

The continuous welded rails are usually loaded directly from the welding assembly line longitudinally onto a sufficient number of either flat or drop-end gondola cars. Loading the rails is most commonly accomplished by the use of a stationary, gasoline-powered single-drum hoist, wire rope and a 1½-in "C" clamp attached to the rail head. In most plants the same hoist arrangement is used to pull the rail through the line prior to its being loaded.

The amount of a train load varies, depending on the distances to be transported and the equipment available, as well as on the extent of the seasons program. As much as three tiers of 13 rails per tier, or a total of 39 long rails have been moved at one time; however, when shorter distances between welding plant and laying site are involved and especially when a not too extensive welded rail program is planned, the more common practice has been to load only one tier of 11 rails per trip.

Located permanently at the receiving end of the loading track is a flat car which is used as a platform and on which is mounted metal guide plates or aprons to aline the rail properly for loading on the cars for transport. The flat or gondola cars used for transporting the rail are equipped in various ways; the device being used predominantly is a single-axle multi roller (one roller per car), mounted over the trucks at one end of each car. The first and last cars of each group have a similar roller arrangement mounted midway on the car to provide added support and also to reduce vibration in transit to the unloading site. On some roads the rollers are not used on the center car of the train; instead, an oak timber of height equal to the rollers is placed across the car to assist in minimizing unnecessary longitudinal movement of the rail load.

For the general practice of transporting a single tier comprised of 11 rails, the roller system design, which allows each component part to be fabricated from materials usually available and without expensive tools, is as follows: each roller is composed of a piece of cold-drawn seamless, mechanically round tubing, outside diameter 3 in, inside diameter 1¾ in, 6¾ in long. Around the inside periphery of each tube are placed 18 pieces of ¼ in diameter, and 1 piece of $\frac{3}{16}$ in diameter, by 6¾ in long maintenance of way welding rod, which serve as the bearings for the roller. The 11 individual rollers

are mounted on a 1¼ in diameter cold-formed steel shaft approximately 8 ft long that extends across the width of the car. The shaft rests on and through intermediate supports fixed to the floor decking at 7-in intervals. Thus 11 separate spaces are provided for 11 lengths of continuous welded rail to be loaded independently. By the above described method ordinary cars can be readily adapted in on-line shops. On roads where extensive welded rail programs have not yet been instigated, portable dolly rollers are used satisfactorily.

After the rails are positioned on the cars they are secured against vertical movement by means of a 1-in by 6-in by 9 ft clamping bar fastened at each end to the roller supports and in contact with each rail head. A less complete system used on conjunction with the portable dollys is to provide a combination arrangement of 1½- and 1¼-in bolts to clamp the rail to the car floor and bearing blocks.

Fig. 1 indicates a modified hold-down device used by some roads on the middle car. It consists of a heavy base plate secured to the flat car deck. The rails are held down by horizontal plates which contact the rail head at four different points.

After the rails are securely fastened, the cars are blocked apart to eliminate slack action. The rails are allowed to move longitudinally only enough to allow negotiation of normal turnouts and main-track curvature. Many roads are transporting continuous welded rail considerable distances in revenue trains without imposing any speed restrictions.

Unloading welded rail may be accomplished by track-mounted lifting cranes placing the rail outside the track on to the tie ends or on the shoulder and also by anchoring the end of the first rail to be unloaded to the existing track structure and dragging the rail onto the ground by moving the train. In the latter case the rail can be unloaded either inside or outside the existing track, as desired. An efficient method of unloading employs a "threader" or "needle eye" mounted on the end car which confines the rail to a particular unloading line as well as reducing the hazard of the rail turning over during the unloading process which is apt to occur particularly on curves.

The track anchor method of unloading welded rail requires the use of a "C" clamp attached to the rail head, and wire rope through the "threader" mounted on the end of the initial car and attached to a "dead-man" anchor which consists of a length of rail 8½ ft long laying beneath the track and against an anchored tie, the space between the dead-man and adjacent tie being wedged with wooden blocks approximately 2 ft long.

Fig. 2 indicates the above-described method of anchoring the first rail to be unloaded to the existing track structure as well as the accurate placement accomplished by using a threader car such as is shown in Fig. 4.

Succeeding rails are unloaded by alining the leaving end of the preceding rail manually prior to its going off the end of the car and making a connection between the two rails, using a lever-operated portable grip hoist and applying special splice bars. After the second rail is unloaded the splice bars are removed and the procedure repeated for the remainder of the load. On subsequent train unloadings the initial rail is attached to the previously unloaded rail using a "C" clamp and ¾-in wire rope. Two rails can be unloaded simultaneously, thereby reducing the unloading time by one-half.

When rail is being unloaded in the center of track and a turnout is encountered, the train is stopped and the rail cut to skip over the turnout limits. If the rail is not laid immediately after being unloaded in the center of the track, it should be spiked at two points each standard rail length to avoid movement that might cause interference with regular traffic.

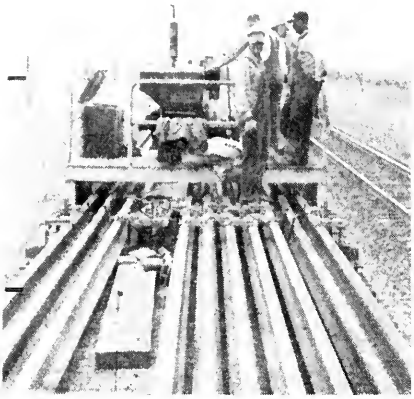


Fig. 1.

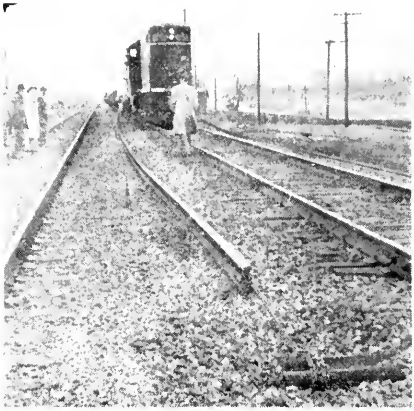


Fig. 2.

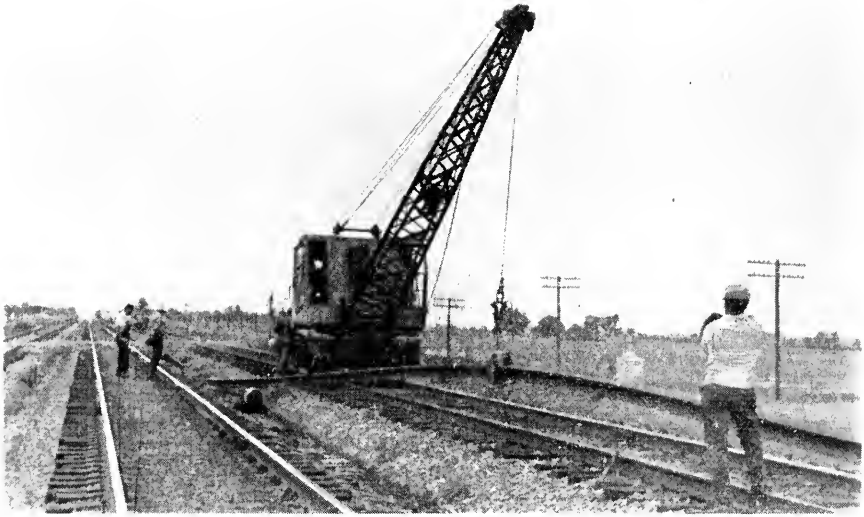


Fig. 3.

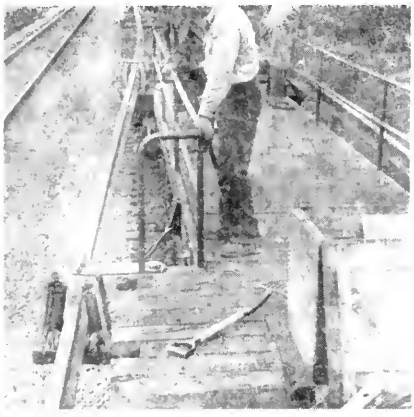


Fig. 4.

Fig. 5.

With sufficient experience it has been found that an equal amount of welded rail can be laid with the same size of gang normally employed to lay conventional jointed rail in a given period. The men ordinarily used to place joint bars and bolts are used to apply rail anchors immediately behind the rail laying operation.

When continuous welded rail has been unloaded outside the track, either a track-mounted or a rubber-tire-mounted crane goes ahead of the rail laying gang and snakes the new rail into the center of the track, using the previously described threader attached to the boom.

In Fig. 3 a track-mounted crane is being used to transfer the previously unloaded continuous welded rail into the center of the track prior to its being laid. Note the threader attached to the boom to facilitate a smooth operation.

After the existing rail has been lined out, the welded rail is installed by a truck-type rubber-tired lifting crane, using the "threader" attachment. This machine should have a versatile maneuverable boom movement. After one rail has been laid this crane pulls the next rail approximately 2 in beyond or past the end of the rail already laid, using a "C" clamp wedged onto the rail head, and attached by four strands of 5/8-in wire rope in blocks. This accomplished, the crane goes ahead approximately 100 ft along the rail to be laid and bends a kink in the rail to take up the 2-in "pull by." In this manner all joints are made with the rail as much in compression as possible, and excess tensile stresses set up within the rail due to its being dragged are released.

Your committee has concluded that there are many and varied techniques and appliances being used on the railroads today to accomplish virtually the same results in loading, transporting, unloading and installing continuous welded rail. The methods discussed in this report are the most generally accepted to date.

Fig. 4 shows one railroad's arrangement of special threaders used for unloading continuous welded rail. Two threaders are attached to the dock at strategic locations on each side of the car to position the rail to be unloaded in the desired position.

When unimportant grade crossings are encountered the continuous welded rail is buried below the surface as shown in Fig. 5 rather than cutting, as is necessary at important highway crossings.

Report on Assignment 7

Number of Units of Work Equipment to Be Repaired by Field Repairmen

S. E. Haines, Jr. (chairman, subcommittee), I. M. Boone, N. W. Hutchison, Jack Largent, H. F. Longhelt, Harry Mayer, M. M. Stansbury, H. A. Thyng.

This is a final report, submitted as information.

A progress report on this subject appears in the Proceedings, Vol. 59, 1958, page 649.

The problem of determining how many machines a field repairman can maintain depends on a number of factors which are outlined in the progress report presented last year, mentioned above. There are many ways to solve the problem. They range from having a large field force and a small shop force, to having a large shop force and a small field force.

There is no rigid pattern of equipment used by the railroads. For instance, a medium-size railroad in the east does not maintain its automotive equipment but rents trucks from an outside rental company which maintains the equipment. All the railroad is concerned with is gas and oil. Some railroads have the maintenance of way people maintain their pile drivers and spreaders. On other railroads this equipment is maintained by the maintenance of equipment shops.

Of the roads indicated on the accompanying chart, Railroad "G" has all of its field men enter the shops to become the shop force during the winter. Railroad "F" has the maintenance of equipment shops do the major repairs to the maintenance of way work equipment. Undoubtedly some of the railroads on the chart farm out some or most of their truck maintenance, depending on where a truck is assigned and where it is when repairs are required. Railroad "D" has three field repairmen, but 75 percent of its shop men go out in the field from time to time to help out. One eastern railroad will have a maintenance of equipment shop man working with maintenance of way field repairman, and this team will combine to repair a maintenance of way machine.

For this study a field repairman listed on the chart as such is called a field repairman because that is his title on his railroad. Obviously, due to the varied conditions, it was necessary to consider all repairmen as a whole, and indicate how the problem is solved on the chart. Field work must be supported by shop work, as they both combine to perform the total maintenance. It was surprising to the committee in studying this subject that conditions are so varied on the railroads studied.

The accompanying chart shows how eight railroads have handled the problem and indicates the results obtained. It should be noted that there is no set pattern for types of machinery on the eight railroads, nor is there a pattern for the number of field repairmen. However, there is a pattern of total repairmen to total number of machines. Those railroads with less than 50 machines per repairman are satisfactorily maintained to well-maintained. Those with 75 machines per repairman encountered maintenance difficulty and much downtime.

The roads indicated on the chart are identified as follows:

A is a large northern railroad in the west.
B is a small railroad in the east.
C is a medium-sized railroad in the east.
D is a large railroad in the midwest.
E is a small terminal railroad in the south central region.

Type of Machine	Railroad							
	A	B	C	D	E	F	G	H
Adzers, tie	27	3	4	44	3	2	3	19
Ballast cleaners Type 1	0	0	0	0	0	0	0	0
Type 2	0	0	1	0	0	0	0	0
Cars - Air dump	0	0	0	0	0	0	0	0
- Ballast drainage Type 1	7	0	0	1	0	0	2	4
Type 2	0	0	0	8	0	0	0	3
- Ballast discers	0	0	0	31	0	0	6	0
- Motor, push and trailer	0	25	0	2610	65	289	1060	1200
Compressors, air	87	8	40	44	6	38	65	40
Compactors, electric vibratory	4	1	3	5	1	0	2	3
Concrete mixers	23	1	5	19	0	0	37	10
Cranes and shovels	27	3	15	23	6	21	41	48
Cribber - Chain type	0	0	0	0	0	2	2	0
- Wheel Type 1	15	0	0	24	0	0	0	0
- Wheel Type 2	0	0	0	4	0	0	0	0
- Drop hammer type	1	0	0	0	0	0	0	1
Conveyors - Bucket type	0	0	0	0	0	0	0	2
Drills - Rail and bonding	54	10	26	168	13	46	30	128
- Earth	3	1	1	6	0	2	1	5
Grinders - Rail portable	23	4	15	97	3	24	52	47
Graders - Motor	0	1	0	4	0	0	0	2
- Pneumatic	0	0	0	0	0	0	0	0
- Hydraulic	1	0	0	0	0	0	0	0
Gager - Track	4	1	0	4	0	0	0	2
Jacks - Power track hydraulic	16	2	6	3	0	5	14	13
Mowers - Weed - Off track	41	3	6	81	1	1	3	50
- On track	31	0	3	104	0	2	7	35
Pile drivers	11	0	2	0	0	0	1	11
Pumps - Water	59	2	14	79	4	8	43	42
Rail layer - Portable	5	0	3	1	0	0	5	3
Rail saws - Portable	66	5	9	102	5	6	34	80
Spike drivers - Mechanical	25	1	4	48	0	2	13	24
Spike pullers - Mechanical	21	4	4	17	0	1	6	13
- Hydraulic	4	1	4	40	1	4	2	10
Sprayers - On track - Oil - Portable	0	1	0	14	1	0	2	30
Spreaders	21	1	0	14	1	3	0	10
Tie borers	19	1	0	1	1	0	4	1
Tie cutters	20	3	5	2	0	0	0	35
Tie handlers - Type 1	0	1	0	13	0	2	0	15
- Type 2	0	1	8	0	0	2	0	0
Tie tamper - Multi-tool air	0	2	0	0	0	2	0	3
- Multi-tool electric #1	3	0	2	6	1	0	6	12
- Multi-tool electric #2	12	0	2	14	0	3	0	16
- Drop hammer type	0	0	0	0	0	2	0	0
- Multi-tool mechanical	0	1	3	0	0	1	0	0
- Electric vibratory off track	14	0	4	299	2	0	17	45
- Self contained	0	0	0	3	0	0	3	20
Track liner - Type 1	8	0	0	0	0	2	1	10
- Type 2	0	1	4	16	0	5	0	0
Track wrench - Type 1	30	0	1	49	0	3	26	30
- Type 2	45	6	20	84	3	10	3	4
Tractors, crawler mounted	34	3	4	54	1	4	30	21
Trucks, automotive	0	62	120	0	6	32	73	512
Trench excavator - Crawler mounted	0	0	0	0	0	0	0	0
- Pneumatic Tire #1	1	0	1	2	0	0	0	0
- Pneumatic Tire #2	0	0	0	0	0	0	1	3
Weed burners	4	0	1	10	1	4	1	3
Welding units - Electric	23	1	11	49	5	5	27	13
- Oxyacetylene	0	3	0	16	8	16	0	0
Yard cleaner - Type 1	1	1	0	4	0	1	0	2
- Type 2	0	0	0	0	0	0	0	0
Other Equipment	359	3	19	162	11	57	94	30
TOTAL	1155	167	377	4393	150	610	1744	2622
Number of field repairmen	6	2	9	3	1	12	36	9
Number of shop repairmen	25	2	8	134	1	-	0	27
Number of machines per field repairman	193	83.5	41.7	1466	150	50.8	48.4	328
Number of machines per shop repairman	46	83.5	47.1	35.4	150	-	0	97
Number of machines per repairman	37.5	41.7	22.2	34.6	75	-	48.4	74.9
	Unsatisfactorily Maintained	Well Maintained	Well Maintained	Well Maintained	Sub-Standard Maintenance	Unsatisfactorily Maintained	Well Maintained	Sub-Standard Maintenance

F is a district of a large eastern railroad.
G is the district of a large northern railroad.
H is a large western railroad.

A time study was made of what a repairman does, how he travels, and how much time he spends on the job actually repairing machines. With 10 railroads and 25 repairmen studied, results on May 5, 1958, were as follows:

25 men worked 203 hr, of which
61 hr were spent traveling (30 percent of the time), and
142 hr were spent working (70 percent of the time).

Four of the 25 men were assigned to large mechanical gangs. The remaining 21 men repaired an average of 1.86 machines per day.

Referring to the chart, in the well-maintained group this would mean that the repairmen would see each machine about every 20 days on the average.

A well-balanced program with trained repairmen, well-equipped trucks with tools and spare parts, enough repairmen so they are not scattered too thinly, and a good preventive maintenance set up, will keep machine downtime to a minimum and production at a maximum.

Union rules, traffic density, terrain, climate, access roads, and policy affect the way any railroad will arrange its maintenance program. It is hoped that this report will serve as a guide to those studying the problem.

In our report last year, the possibility of having a weighted rating for units of work equipment was proposed. The committee made such a rating based on their estimates. But because it was based only on opinion and not on facts, the idea was discarded as not worthwhile. A very exhaustive study with records over a period of years would be required to make it factually accurate. By the time it was completed, many of the machines would be obsolete.

There are two conditions under which this report can be used. One is the ideal condition where a railroad is being completely reorganized; the other is where a railroad finds that it has too many machines for the repairmen to maintain. This will result in out-of-service time for machines. The latter railroad will know it is in trouble and, by referring to the progress report in Vol. 59 of the Proceedings, it can take those steps into consideration first and increase the efficiency of repairmen. After those steps have been taken, another look at this report may convince the management that more repairmen are required.

Report on Assignment 8

Fuel and Lubrication Trucks for Use with Mechanized Gangs

L. B. Cann, Jr. (chairman subcommittee), T. S. Bean, E. H. Fisher, R. A. Hostetter, W. F. Kohl, P. G. Petri, T. J. Reagan, N. E. Smith, R. S. Stephens.

This is a final report, submitted as information.

Your committee has developed that there is only one manufacturer building trucks suitable for handling the fuel and lubrication needs for mechanized timbering and surfacing gangs and heavy earth-moving equipment. Reports from various railroads indicate that there are two large systems that have designed their own specific trucks to handle this problem; that the majority is still hauling the fuels in small pickup trucks

or section trucks out to the job; and that the lubrication equipment is retained with the tool equipment on each individual machine.

In the following your committee outlines first (under item 1) the manufacturer's equipment that is now available as a unit for purchase, along with its specifications:

1. Unit to Provide the Following:

Fuel

Two-compartment tank with double bulkheads and emergency valves.

Total tank capacity 1200 gal, with tentative division of 600 and 600. This can be varied to suit individual requirements.

Fuel to be dispensed through two systems to prevent contamination or explosion hazard. Fuel systems are to be hydraulically operated with power being supplied through power take off on chassis transmission. Hose reels and product pumps are to be hydraulically driven. Fuel is to be dispensed through meters with reset counters. Printing counters are available as an extra. Hose reels are to be equipped with 100 ft of fuel hose and automatic shut-off nozzles.

Air—ASME Reservoir

Air is to be carried in 80 cu ft reservoir located in street-side box. Air is to be supplied by 7½ air compressor mounted on truck engine. This compressor will also provide air for chassis air brakes. To safeguard against loss of air for chassis brakes, the air reservoirs are to be separated by a pressure-reducing valve to keep from drawing less than 60 psi from chassis system. Air hose reel is to be provided with tire chuck connection. Greasing and water equipment are to be powered from this reservoir.

Water—ASME Reservoir

Water is to be carried in 30-gal reservoir located in street-side box above air reservoir. Water to be forced from tank with air pressure and be dispensed through hose reel.

Lube

Three lubricating guns with reels are to be provided. Two units are to be high-pressure type capable of dispensing high-pressure lubes or track roll lube. One unit to be low-pressure type for use on gear or motor oils. Lubricating guns are to be powered with air from air reservoir. Lubricating guns to be type that fit on standard grease cans.

Oil

Space to be provided to carry eight 5-gal oil cans. Case oil can also be carried in this space.

Chassis

Engine—V8, 272 cu in.
Rear axle—16000 lb, 2-speed.
Front axle—7000 lb.
Brakes, service—Full air.
Brakes, hand—Propeller shaft.
Clutch—11 in.
Transmission—Four-speed.
Fuel tank—18 gal.
Wheels—Cast.
Tires—9:00 x 20 x 10 ply.

Fuel truck purchased as a unit.

Tank construction—ICC, MC–303.
Compartments—Two, divided 600–600 (optional).
Bulkheads—Double for Class 1 and 2 products.
Surge heads—As required.
Flashing—Full length with drains.
Sills—Steel with oak shock strips.
Bumper—Rigid, mounted on chassis frame.
Walkways—Non-skid, both sides.
Steps—Front, both sides.
Platform—Tapered, rear.
Cabinet curb side—Underslung cabinet with full-height opening.
Cabinet, street side—Underslung cabinet with full-height opening.
Cabinet, curb side—Horizontal cabinet above wheel.
Manholes—Approved 16 in with 10 in fills and vents.
Outlets—Flanged.
Capacity indicators—Each compartment, not set or sealed.
Lamps—To meet state and ICC requirements.
Emergency valves—To meet gasoline-carrying requirements.

Complete Hydraulically Powered Pump System

PTO—Heavy duty.
Drive shaft—Heavy duty.
Hydraulic pump—Hannay HD–3, or equal.
Product pumps—Blackmer TN–1½, or equal.
Product motors—Hannay HD–2, or equal.
Hose reels—Hannay hydraulic drive, or equal.
Control valves—Hannay HD–4, or equal.

Hose—Two, 1 in by 100 ft.
Nozzles—Two, automatic shut-off.
Meter—Two, fuel meters with counter.

Lube and Grease Dispensing Equipment

Air tank—80-gal ASME code reservoir, supplied from truck compressor.
Water tank—30-gal ASME code reservoir. Water discharged with compressed air.
Air hose reel—Spring return reel with ½-in hose and tire inflation chuck.
Water hose reel—Spring return reel with ½-in hose and water nozzle.
Lube dispenser—Two high-pressure lubricating guns with spring return hose reels and grease nozzles.
Oil dispenser—Low-pressure lubricating guns with spring return hose reel and nozzle.

2. Specifications for Cab and Chassis Complete with Specially Equipped 12-Ft Platform Bed, Type FL—(Fuel and Lube), for Use in Servicing Mechanized Gangs

Intent

These specifications cover the furnishing of the latest-model gasoline-engine truck complete with specially equipped bed having a minimum gross vehicle rating of 14,000 lb.

General Requirements

a. Furnish cab and chassis complete with specially equipped platform bed.
b. The truck furnished shall be the manufacturer's latest listed and published stock model which meets all the applicable requirements of the specifications.
c. Deviations from the provisions of these specifications must be listed on the attached inquiry form, which is a part of the bid. The bidder must comply with all the provisions of the specifications except those items which are listed as deviations.

Detail Requirements

a. Engine displacement: minimum 235 cu in.
b. Clutch: The clutch shall be a heavy-duty type with a minimum diameter of 11 in.
c. Transmission: the transmission shall be the manual shifting type with a minimum of four forward speeds and one reverse speed.
d. Rear axle and springs: two-speed rear axle with helper springs.
e. Cab to axle dimension—84 in.
f. Brakes: service brakes shall be heavy-duty power type acting on all four wheels. A mechanical parking brake shall be provided.
g. Six tires shall be 8.25 x 20, 10 ply with tubes and mounted on interchangeable wheels having 6-in rims. Four rear tires to be road lug type.
h. Shock absorbers: to be double-acting front and rear.
i. Mud flaps: contour type.
j. Frame: the frame shall have adequate strength to carry the gross vehicle weight specified.
k. Electric system: a complete electric starting system, including generator and voltage regulator, shall be furnished. It shall be a 12-v system with a minimum

25-amp generator and a minimum 70 amp-hr battery. Battery ratings shall be at the 20-hr rate, in accordance with SAE standards.

l. Lights: all lights in accordance with current legal requirements shall be affixed to the truck and will include front and rear truck identification markers.

Equipment

The following equipment and accessories shall be furnished:

a. Oil filter—heavy duty.
b. New type dry air cleaner—heavy duty.
c. Fuel tank with a minimum capacity of 17 gal.
d. Front bumper.
e. Heater and defroster—fresh air intake type.
f. Electric horn.
g. Rear view mirrors: (1) inside-tilting type, (2) truck-type outside rear view mirrors on both sides of the cab. These mirrors shall be rectangular in shape and the minimum dimensions shall be 5 by 10 in. Diagonal braces shall be used for reinforcement.
h. Standard jack and lug wrench.
i. Windshield wipers—Dual, positive action.
j. Twenty pound CO_2 fire extinguisher.
k. Flares, to be installed to meet legal requirements.
l. Six copies of truck service and maintenance manual with parts list and repair data (for initial unit only).

Body Requirements

Body furnished shall be platform style with 145-in length and 88-in width, built and equipped as per attached drawings.

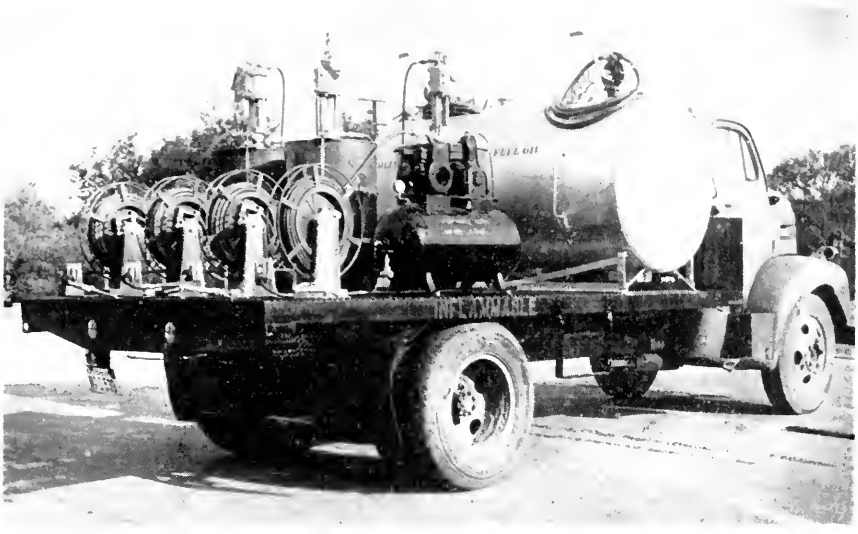
Special Equipment

a. Two Bennett No. 2008–G pumps, or equal, with 25 ft by ¾-in hose and two John Wood No. E–0684 Fill-O-Matic nozzles, or equal, with clips, installed in top of 275-gal fuel tanks shown on attached drawing.
b. Three-hp steel barrel pumps, for use on 55-gal oil drums.
c. One 7½-cu ft fan belt driven air compressor kit, including drive kit, air supply kit and tank kit, to be installed, (kit must be for type of truck or engine specified in bid).
d. One portable utility pump, with hose and nozzle for transmission lube.
e. One Alemite pump and drum cover No. 8559–H, or equal, to be furnished and fitted with the following equipment:

One Alemite No. 6322 control valve, or equal.
One Alemite No. 44734 adapter, or equal.
One Alemite No. 53320 swivel, or equal.
One Alemite No. 317875 hose, or equal.
One Alemite No. 319747 screen, or equal.

Pump to be connected with 25-ft of high-pressure hose and fittings with quick disconnect coupler on the air reservoir for use on top of grease drum and protected by cover.

f. One Binks No. 140 siphon gun, or equal, equipped with 25-ft of ½-in hose



Specially designed fuel truck for servicing mechanized gangs.

and self-sealing quick disconnect coupler for connection to air reservoir, complete with the following equipment:

One Lunkeheimer No. 1841 ¼-in air nozzle, or equal.
One Shrader No. 8052–12 check unit, or equal.
Two Shrader No. 8050–11 ¼-in adapters, or equal.
One Shrader No. 8159–B air chuck, or equal.
One Shrader No. 9350 air gage, or equal.

g. Eight padlocks and keys: Master #105 "Key-a-Like", or equal, for pumps and boxes.

h. Two 2-qt oil measures.

Undercoating

All metal parts under the vehicle shall be coated with undercoat.

Painting

Exterior of vehicle, except chrome:

a. Prime coat.

b. Finish to be AREA yellow.

3. System Truck with the Following Equipment for Grading Gangs:

One fuel tank, 42 in diameter by 93 in long, with partition holding 435 gal of fuel oil and 65 gal of gasoline with 2 Tokheim high vacuum hand pumps (Model 688), or equal, with bung adapters and two pieces of hose for fuel 25 ft long. Hose to have 2 Fill-O-Matic nozzles No. 1811 with 1829 bushing, or equal.

One air compressor, 7½ cfm with appropriate air-cooled engine and 18- x 38-in air reservoir.

Truck designed for servicing grading gangs.

Three Alemite pumps, Model 317940, or equal, for No. 30–90 motor oil, one for high-pressure lubricant.

Four reels, Model 320980 (1 for No. 30 and 1 for No. 90, and 1 for H.P. lubricant and 1 for air). Air hose 50 ft long, 3 hose for lubricant 20 ft long.

Four No. 32091 roller-type hose guide and bracket assembly

One 30-lb dry chemical fire extinguisher.

One vaporizing liquid fire extinguisher, 1½ qt, mounted in cab.

One Alemite, Model 7421, "Adjustaslot" control valve for H.P. lubricant, or equal.

One Alemite, Model 6611, motor oil hand meter, or equal.

One Alemite, Model 7490, gear oil control valve, or equal.

One Alemite, Model 306586, tire gage and check, or equal.

One Alemite, Model 6782, booster gun, or equal.

4. **The Following Equipment Is Necessary to Equip each Timbering and Surfacing and Rail Gang Truck:**

Two oval fuel tanks, 265-gal capacity each, mounted on front of body on each side and parallel with body, walkway between tanks. Each tank has Tokheim hand pump, Model 688, or equal, with 25 ft of hose and Fill-O-Matic, or equal, nozzle.

Four barrel racks with hold-down bolts.

Four barrel pumps, Tokheim, Model 688, or equal, with 8 ft of hose and 4 Tokheim, or equal, nozzles No. 22.

One 30-lb dry chemical fire extinguisher.

One vaporizing liquid fire extinguisher, 1½ qt, mounted in cab.

Body of truck is 8 ft wide and 14 ft long, floored with expanded metal, spec. 4.27 lb.

Report on Assignment 10

Four-Cycle vs Two-Cycle Gasoline Engines Used on Small Equipment

R. J. Smith (chairman, subcommittee), S. E. Haines, Jr., R. A. Hostetter, M. E. Kerns, H. F. Longhelt, Paul Martin, Harry Mayer, V. W. Oswalt, Sr., T. H. Taylor, H. A. Thyng, and F. E. Yockey.

This is a final report, submitted as information.

Practically all of the reciprocating internal-combustion engines built today operate on either the two-stroke cycle or the four-stroke cycle. For the purpose of this report, the word stroke will be omitted and the designation "two-cycle" or "four-cycle" will be used. Also, comments will be confined to engines using gasoline as a fuel, and narrowing the field still further, only engines of less than 15 hp will be discussed.

The Two-Cycle Engine

This type of engine delivers a power impulse for each revolution of the crankshaft. There are two strokes of the piston for each revolution—the power stroke when the piston is traveling away from the cylinder head, and the compression stroke when the piston is traveling toward the cylinder head. Actually, two things are taking place in a two-cycle engine during each stroke. On the power stroke, the fuel mixture is being compressed in the crankcase, and on the compression stroke the fuel mixture is being drawn into the crankcase. The compressed gases in the crankcase are admitted to the cylinder through openings in the cylinder wall that are uncovered by the piston near the end of the power stroke. The same holds true for the exhaust, which passes out through openings in the cylinder wall and are uncovered a small fraction ahead of the inlet port.

Major advantages claimed for the 1- to 5-hp air-cooled, two-cycle engines are:

1. Lightweight—more power per pound. Two-cycle engines produce more power per pound of weight than four cycle-models of comparable horsepower.

Manufacturers of small, air-cooled, two-cycle engines have exploited the advantages of using aluminum or magnesium alloys in designing lightweight engines for portable equipment which can be carried by one or two men. In the case of back-packed equipment, such as small brush cutters which are hand held during operation, these lightweight features have increased importance as every additional pound of weight adds to the fatigue of the operator.

2. Simplicity—less maintenance cost. Two-cycle engines have about one-third fewer moving parts than a comparable four-cycle model. This design eliminates camshafts, timing gears, valve assemblies and the need to grind valves. The fewer number of wearing parts results in easier maintenance and less maintenance cost.

3. Assurance of constant lubrication. Two-cycle engines are lubricated by the oil in the oil—gasoline fuel mixture, and lubrication of all parts is assured at all times, provided that the proper mixture is used in accordance with the manufacturer's recommendation. When the engine is started, clean, fresh oil reaches the cylinder walls in full strength before the engine fires, regardless of temperature, providing a complete change of oil each revolution. When the choke is used on cold mornings, excess gasoline can do no harm as there is also more oil to protect the metal parts, and on hot days, fresh, cool oil is drawn in with the incoming combustible mixture. In addition, two-cycle engines need only be drained of fuel for storage or long periods of idleness.

4. All-angle operation. Two cycle engines do not require an oil sump and can be operated at any angle. Chain saws with diaphragm carburetor are frequently used in the upside-down position. This feature is also important with portable pumps, blowers and generators, as it eliminates the need to level these units to assure proper lubrication.

The better two-cycle engines designed for heavy-duty service carry heavy-duty ball-bearing or roller-bearing mains at each side of the crankshaft. High-speed, two-cycle engines are generally equipped with forged-steel crankshafts, and forged-steel connecting rods, with heavy-duty needle bearings at both wrist-pin and crank-pin ends.

Two-Cycle, Water-Cooled Engines

Generally speaking, two-cycle, water-cooled engines develop maximum torque at low speeds, in most cases at less than 1000 rpm, and can run in either direction of rotation, thus in specific applications, such as motor cars, eliminating reverse gearing when power applications call for a change of direction.

One of the major advantages claimed for two-cycle, water-cooled engines with battery and coil ignition as used in motor cars, is the fact that anyone with but a small amount of mechanical ability can keep them in good operating condition.

Water-cooled, two-cycle engines are rarely, if ever, used for stationary service. This is because they do not have a system for cooling the water, and the water boils in the cooling system. Most motor-car engines have steam condensers that conserve the water. In stationary service, these engines would require an auxiliary water supply to replace that which would boil away.

The 10- to 14-hp engine weighs less than the 8- to 13-hp engine. This is because the former is built largely of aluminum.

Comparing water-cooled, two-cycle engines against air-cooled, four-cycle engines with reverse gears for motor car use, they weigh about the same. That is, the air-cooled, four-cycle engine and companion reverse gear weigh approximately the same as a water-cooled, two-cycle, motor-car engine. The two-cycle engines, of course, do not need a reverse gear since they are able to run in either direction.

As for a cost comparison of the same two engines, that is, the water-cooled, two-cycle, and air-cooled, four-cycle with a reverse gear, it appears that the latter costs about 10 percent more than the water-cooled two-cycle.

The question often arises about the number of hours of operation of a two-cycle, water-cooled engine before port cleaning is necessary. Naturally, the frequency of port cleaning is subject to many variations, dependent upon the quality of gasoline and oil, the type of service and the distances traveled per day. Port cleaning at 350-hr intervals is considered average.

Mixing of gasoline and oil for two-cycle engines is not difficult, but it must be done with care and accuracy for best results.

When oil and gasoline are mixed at a central location and shipped as "mixed gasoline-oil" it will not meet all the manufacturer's recommendations. Satisfactory results cannot be obtained by putting the two ingredients into the fuel tank separately. The gasoline and oil should be accurately measured and thoroughly mixed before being put into the fuel tank to insure a satisfactory fuel for good operation and minimum carbon build-up.

Four-Cycle Engines

In the four-cycle engine there are four piston strokes and two crankshaft revolutions for each power stroke. These are: the intake, compression, power and exhaust strokes. The passage of the gases into and out of the combustion chamber is controlled by valves actuated by a camshaft that is driven from the crankshaft.

Four-cycle engines have more moving parts than a two-cycle engine but are capable of higher speeds if required. The maximum torque of industrial engines is usually obtained between 1400 and 2000 rpm. They idle well and can be throttled adequately to meet part-load conditions. The oil system is separate from the fuel system, providing ideal lubrication and/or fuel to meet actual operation conditions. Between oil changes it is essential to maintain the proper oil level, if trouble-free operation is to be expected. While oil changes at regular intervals are highly recommended, the number of hours between changes will vary with operational conditions. Excessive heat, dilution and foreign matter such as dirt, which frequently accompanies the operation, will actually determine the oil change frequency. Oil should be changed before it becomes so full of contaminants that its lubrication properties are seriously impaired. The addition of new oil daily or as needed prolongs the lubricating characteristics, but does not ever restore it completely.

Major advantages claimed for four cycle engines are:

1. Ease of starting. Four-cycle engines have a better reputation for easy starting, due in part to positive breathing and scavenging which is inherent in all four-cycle engines, and also due to the freedom of spark plug fouling. The low vaporization of the fuel makes it easier to ignite.

2. Quiet operation. Four-cycle engines are ordinarily more quiet in operation than the two-cycle models. There are twice as many explosions per minute on the two-cycle models at any given speed, so the average observer will say that the four-cycle engine is running much slower than the two cycle engine, while in reality they are operating at exactly the same speed. Four-cycle engines are less sensitive to back pressure, so it is easier to design a quiet, four-cycle muffler.

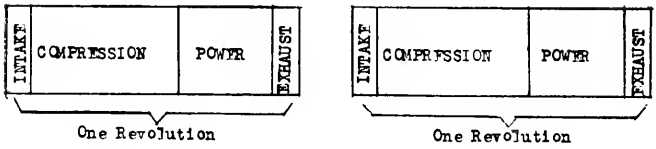
3. Rated power periods longer. Four-cycle engines can be expected to maintain their rated power for longer periods than two-cycle engines. Service frequencies for cleaning the exhaust ports of carbon deposits on two-cycle air cooled engines of less than 10 hp average approximately 40 hr. Service frequencies for cleaning combustion chamber carbon deposits on the four-cycle engines of less than 15 hp average approximately 100 hr, and valve servicing periods of 500 hr frequencies are considered average.

4. Oil system separate from fuel system. Four-cycle engines use clear gasoline. One of the prime reasons for ignition trouble is fouled spark plugs. Fuels containing lubricating oils not only form more tenacious deposits, which gradually foul spark plugs, but also the gasoline—oil mixture is a little harder to ignite because of its somewhat higher vaporization point.

DIAGRAM OF ENGINE OPERATION

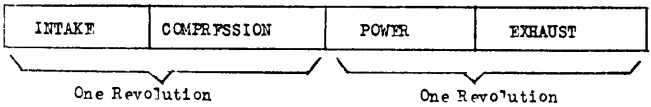
TWO CYCLE ENGINE

Operating Sequence



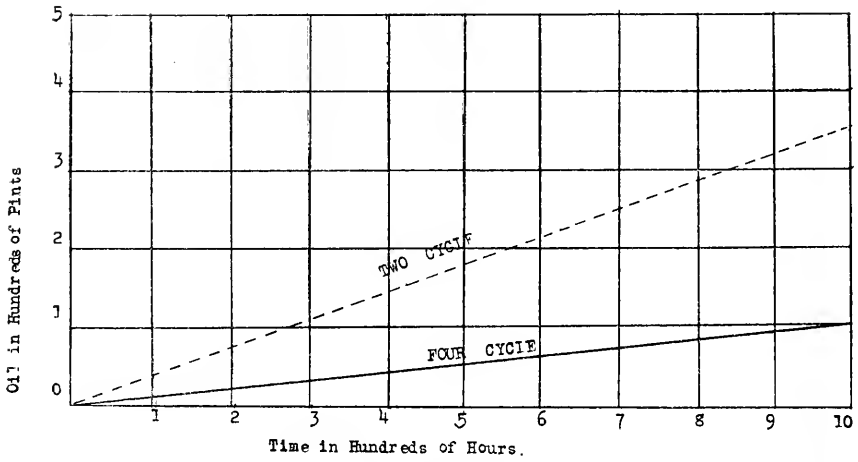
FOUR CYCLE ENGINE

Operating Sequence



OIL CONSUMPTION OF TWO CYCLE AND FOUR CYCLE ENGINES

5 to 8 HORSEPOWER CLASS



OPERATING CONDITIONS

1. Speed - 3/4 Throttle - Two Cycle = 1200 RPM .72 Gals fuel per hr.
   Four Cycle = 2800 RPM .66 " " " "

2. Load - 3/4 Rated Output.

3. Lubrication - Two Cycle - Gasoline-Oil Mixture - 16 : 1 Ratio
   Four Cycle - Separate Oil System with Crankcase Capacity of 5 Pints.
   Oil changed every 50 hours of operation.

Four-Cycle Engines

The Advantages Are:

1. Easier starting.
2. Quiet operation.
3. Better spark plug life.
4. Fuel does not need mixing.

The Disadvantages Are:

1. Valve trouble.
2. Combustion chamber build-up.
3. More wearing parts.
4. Oil levels must be maintained.
5. Crankcase oil must be changed.
6. Higher maintenance costs.

Two-Cycle Engines—Air Cooled

The Advantages Are:

1. Light weight.
2. Simplicity.
3. Constant lubrication.
4. All angle operation.
5. Lower maintenance costs.

The Disadvantages Are:

1. Spark plug fouling.
2. Carbon build-up in ports.
3. Fuel must be mixed properly.
4. Oil consumption is considerably higher.

Summary

Four-cycle, air-cooled engines of less than 10 hp are usually of single-cylinder design. Four-cycle, air-cooled, two-cylinder engines from 10 to 18 hp may be in-line or of opposed-cylinder design.

Single-cylinder, two-cycle, air-cooled engines are available up to 5 hp.

Two-cycle, water-cooled engines up to 8 hp are of single-cylinder design.

The two-cycle, water-cooled engine from 10 to 14 hp is of the opposed-cylinder design. In most cases, water-cooled engines in this group are not a complete power package, i.e., the gasoline tank, air cleaner and battery box are not part of the engine assembly.

Generally, air-cooled engines in this group are supplied as a complete power package ready to be run. Various items such as air cleaners, mufflers, gasoline tank, starting means, fuel filter, a complete magneto ignition system, and the blower or fan for cooling, are all part of the engine assembly.

Starting methods include hand cranks, ropes, rewind and recoil starters, as well as electric starters. Rope, rewind and recoil types are most widely used on the smaller engines.

Cranks are generally used on the larger engines.

Electric starting is an optional feature on a few of the larger engines. The addition of a storage battery, starting motor, and battery charging generator, could more than

AVERAGE FUEL CONSUMPTION 4 CYCLE AIR COOLED ENGINES
COMPLETE WITH COOLING FAN, AIR CLEANER & MUFFLER - FUEL GASOLINE

Approx. H.P.	LOAD	APPROXIMATE GALLONS PER HOUR AT --- r.p.m.										Weight of Bare Eng.
		1600	1800	2000	2200	2400	2800	2800	3000	3200	3400	3600	
2.5	FULL	.29	.32	.39	.46	.49	.51	.54	.59	.63	.65	.67	
to	3/4	.24	.26	.29	.31	.36	.39	.44	.49	.52	.57	.59	70 - 80
6.	1/2	.18	.20	.23	.26	.29	.32	.35	.37	.41	.44	.45	
3.5	FULL	.37	.41	.45	.50	.55	.59	.63	.67	.71	.73	.75	
to	3/4	.31	.35	.38	.43	.48	.50	.54	.57	.60	.62	.64	80 - 90
7	1/2	.25	.27	.30	.33	.36	.39	.41	.44	.46	.48	.50	
4.7	FULL	.45	.51	.58	.63	.69	.73	.77	.81	.85	.87	.89	
to	3/4	.38	.44	.49	.53	.58	.62	.66	.69	.72	.74	.76	105 - 115
9.2	1/2	.30	.34	.38	.42	.46	.49	.52	.54	.56	.58	.60	
7.7	FULL	.90	1.00	1.12	1.22	1.32	1.35	1.38	1.42				
to	3/4	.78	.83	.89	.95	1.02	1.08	1.13	1.19				165 - 185
12.5	1/2	.63	.68	.78	.82	.87	.92	.99	1.00				
10	FULL	1.10	1.28	1.41	1.67	1.70	1.74	1.86	1.98	2.02	2.10	2.15	
to	3/4	.83	.96	1.16	1.27	1.33	1.36	1.51	1.57	1.63	1.64	1.70	170 - 200
18	1/2	.70	.75	.79	.88	.94	1.02	1.10	1.19	1.25	1.34	1.39	

Fuel consumption chart for Two Cycle Air Cooled Engines includes the lubricant premixed with the fuel. This should be taken into consideration in comparing fuel and lubrication costs of operation.

AVERAGE FUEL CONSUMPTION TWO CYCLE AIR COOLED ENGINES FUEL OIL-GASOLINE MIXTURE

H.P. Approx	LOAD	APPROXIMATE GALLONS PER HOUR AT --- r.p.m.											Weight of Bare Eng.
		1600	1800	2000	2200	2400	2600	2800	3000	3200	3600	4000	
2.5	FULL	.37	.40	.45	.51	.54	.57	.59	.64	.68	.72	.75	.79	
to	3/4	.31	.33	.34	.35	.40	.44	.48	.53	.56	.62	.68	.74	25 Lbs.
5.0.	1/2	.23	.25	.27	.29	.32	.36	.38	.40	.44	.47	.50	.53	

Fuel consumption chart for Two Cycle Water Cooled Engines includes the lubricant premixed with the fuel. This should be taken into consideration in comparing fuel and lubrication costs of operation.

AVERAGE FUEL CONSUMPTION - TWO CYCLE WATER COOLED ENGINES FUEL OIL-GASOLINE MIXTURE

Approx. H.P.	LOAD	APPROXIMATE GALLONS PER HOUR AT --- r.p.m.						Weight of Bare Engine
		600	800	1000	1200	1400	1600	
5	FULL	.47	.60	.76	.87	.97	1.03	
to	3/4	.44	.56	.63	.72	.79	.84	135 Lbs.
8	1/2	.35	.45	.50	.57	.61	.64	
8	FULL	1.35	1.77	2.02	2.34	2.60		
to	3/4	1.27	1.45	1.87	1.93	2.10		348 Lbs.
13	1/2	1.00	1.21	1.32	1.53	1.62		
10	FULL	.83	1.10	1.40	1.75	2.00	2.23	
to	3/4	.78	1.03	1.16	1.45	1.62	1.79	160 Lbs.
14	1/2	.61	.81	.92	1.15	1.25	1.37	

double the weight of many small engine installations. The weight of an electrical starting system also dictates the use of a magneto.

One of the advantages of air-cooled engines is the fact that there is no danger of boiling or freezing. This design eliminates water hoppers or water jackets, radiators or condensers, checking of water levels at regular intervals, and the need to buy anti-freeze.

All engines should be equipped with an efficient air cleaner. Either the dry-element type or the oil-bath type of air cleaner will perform their functions adequately, if serviced according to the manufacturer's recommendations, and will help to prolong the life of the engine.

Report on Assignment 12

Shop Machinery and Equipment Needed for Work Equipment Shops

J. W. Cummings (chairman subcommittee), W. T. Hammond, Jack Largent, C. F. Montague, P. G. Petri, H. C. Pottsmith, J. W. Risk, R. J. Smith, G. L. Zipperian.

This is a final report submitted as information. A previous report on this subject was submitted by this committee in 1946 and may be found in the Proceedings, Vol. 47, pages 182 to 192.

From experience gained since publication of the previous report and the acquisition of many more complex and different types of machines, it is the opinion of the committee that the shop machinery and equipment recommended for use in 1946 should be reviewed and studied with a view to revising the requirements to meet current demand and include additional and different types of tools and equipment needed to efficiently carry out the repair work on machines of both the older and the most recent types.

It is the opinion of the committee that the amount of equipment needed in a maintenance of way shop should be in direct proportion to the number of machines maintained by a particular railroad. This also applies to the number of machine tools which could be used in a medium or large shop.

The regional or system shop should be set up to perform heavy specialized repairs to all classes of machines, new or old, and should be equipped accordingly.

The district or division shop or small maintenance of way repair shop can perform other classes of work, which consist largely of replacing small parts, etc., where special machines are not required to make repairs.

With this arrangement, it is felt that roadway machines can be maintained in the best condition and in the most economical manner.

The following lists the shop machinery and equipment recommended for use in: (1) regional or system shop, and (2) district or division shop.

Regional or System Shop

Torque wrenches.
Impact wrenches.
Socket wrench sets, ¼ in, ½ in and 1 in drive.
Combination box and open end wrenches.
Ignition point wrenches.
Pipe wrenches—6 in to 36 in.
Set of thickness gages 10 in long—0.002 to 0.050
Set of thickness gages 4 in long—0.002 to 0.050
Heavy-duty wheel, sprocket and gear pullers.
Heavy-duty spanner and ring wrenches.
Taps and dies, national coarse and national fine.
Drills of all sizes.
Screw extractors all sizes.
Screw clamps—1 in to 12 in.
Taper pin reamers.
Taper motor car wheel reamers.
Expansion reamers for bushings—½ in to 2 in, with line reaming extensions.
Set of gasket punches.

Flanging tool—⅛ in to ¾ in for copper tubing.
Hand tachometer.
Electric tachometer.
Circular hole saws—⅝ in to 3 in.
Gasoline blow torch.
¼-in electric drills.
½-in electric drills with bench stand.
¾-in electric drills with bench stand.
Work benches equipped with vise and tool drawers.
Air compressor (portable).
Garage-type dolly jacks.
Anti-freeze tester.
Soldering irons.
Soldering iron furnace.
Soldering torch for radiator repairs.
Soldering acid gun for radiator repairs.
Radiator test tank and rubber ball test plugs.
Air reduction valve for testing radiators.
Hand bolt cutters and nippers.
Bevel protractor and combination square set.
Device for testing air compressors and air tools.
Automotive floor jacks.
Transmission jacks.
Portable hoists.
Bench grinders—8 in to 10 in.
Starter repair tools.
Safety cleaning vat.
Cylinder ridge reamers.
Cylinder hone.
Cylinder boring bar.
Cylinder sleeve pullers.
Piston vise.
Piston ring measuring tool.
Piston ring compressors.
Piston ring groove cleaner.
Piston pin honing machine.
Piston lathe and grinder.
Connecting rod aliner.
Connecting rod bearing boring tool.
Cylinder head surface grinder.
Crank shaft grinder.
Main bearing line boring bar.
Motor repair stands.
Dynamometer engine test equipment (30–300 hp)
Dynamometer engine test equipment (0–50 hp)
Spark plug cleaner and tester.
Spark plug gap gage.
Complete set of spark plug taps.
Valve seat grinder.

Valve seat inserter.
Valve refacer.
Valve guide removers and installers.
Valve guide reamers.
Valve spring lifters.
Valve spring tension tester.
Electric valve grinder.
Hand valve grinders.
Set of carburetor repair tools.
Compression tester.
Fuel pump tester.
Wheel balancer.
Front end alinement equipment.
Headlight tester and adjuster.
Pressure lubricating unit.
Braker bleeder.
Brake cylinder hone.
Brake drum lathe.
Timing light.
Ampere, volt and resistance tester.
Cam angle meter.
Electric laboratory testing set for generators, regulators, starters, distributers, condensers, coils and magnetos.
Armature growler.
Mica undercutter.
Armature winding equipment.
Armature dipping vat.
Armature baking oven.
Armature bearing pullers.
Magnet meter.
Circuit analyzer set.
DC ammeters (0 to 6 amp and 6 to 30 amp).
DC voltmeter (0 to 150 amp and 0 to 300 amp).
AC and DC tong tester (0 to 30 amp and 0 to 600 amp).
Brush spring tension gage.
Storage battery analyzer.
Battery terminal cleaner.
Battery cell tester.
Hydrometer for battery acid test.
Battery carrying straps.
Battery wax melting pot.
Generator and starter pole shoe spreader.
Generator and starter pole shoe screw remover.
Armature dressing stones.
Starter current indicator.
Exhaust analyzer.
Tube vulcanizing kits.
Tubeless tire repair kit.
High-pressure pump for making hydrostatic test of tanks and air reservoirs.

Radiator test tank and repair kit.
Set of body and fender tools.
Motor car wheel mounting gage.
Set of motor car wheel gages.
24-in band saw.
Electric hand saws.
Electric hand sanders.
Standard set of carpenter tools.
Glass cutters.
Milling machine.
Pony planer—24 in.
Rip and cut off saw—size 16 in with dado heads.
Jointer—12 in.
Open fire furnace.
Anvil and blacksmith tools.
Sheet metal shears—60 in.
Horizontal wheel press—200 ton.
Vertical turret lathe.
Key seating machine.
Connecting rod and main bearing babbiting-equipment, including melting pots, jigs, etc.
Spot welding machine.
Power sheet metal shear.
Power sheet metal break.
Power sheet metal rollers.
Power boiler plate and angle iron shear.
Hydraulic hose connecting, installing equipment.
Bridge cranes—one 30 ton, two 10 ton.
Electric or gas-electric mobile shop crane.
2000 lb capacity trolley-type electric hoist.
Portable electric welder—300–400 amp.
Heavy-duty extension bed gap lathe 20-in swing, with 40 in by 40 in swing extension bed opened, complete with accessories.
Horizontal shaper with 30-in travel.
6-ft radial drill, heavy duty with box table.
Universal milling machine No. 4.
Stationary electric powered hydraulic press—150 ton capacity.
Furnace for annealing and hardening.
Hand-powered portable hydraulic press—50–100 ton.
Heavy duty double-end pedestal grinders—14-in wheels
Double-end pedestal grinders—10-in wheels for tools.
Power hack saw.
Lathe tool grinder.
High-speed friction saw for cutting hydraulic hose.
Semi-automatic welding machine.
Metal spray equipment for reclamation of shafts, hydraulic rams, etc.
Manual and hydraulic jacks—25–75 ton capacity.
Monograph shape cutting machine.
Steam cleaning machine.

Hot dip cleaning tanks.
Hydraulic test rack.
Unit injector rebuilding kit.
Magnet charger.
Distributor tester.
Coil condenser tester.
Brake and clutch relining and riveting machine.
Flow testing meter for hydraulics.
Resonant reed tachometer.
Injector testing kit.
Battery charger.
Portable chain blocks—½ ton, 2 ton capacity.
Motor analyzer instrument kit (automotive).
Paint shop equipped with blower, dryer and sprayer.
Oxyacetylene welding and cutting equipment.
Test track, preferably outside but close to shop.
Inspection pits.
300-amp electric welding unit (portable).
Pneumatic off hand grinder—6-in wheel.
Vertical drill press—2 in capacity.
Combination pipe and bolt threading machine.
5-ton arbor press.
Lathe—10-in swing, 4-ft centers.
Tool room equipped with small grinders, electric drills, slings, chains, punches, straight edges, gages, inside and outside micrometers, etc.
Stud removers.
Bearing scrapers.
Snap ring removers.
Dial indicators.
Pipe taps and ratchet dies—⅛ in to 1 in.
Straight edge—36 in.
Steel measuring tape—50 ft.
Carpenters level.
Electric hand grinder 8-in wheel.
Electric light extensions.
Brake drum checking gage.
Pipe vises.
Welding table and face plate.
Body and fender straightening tools.
Paint spray booth and equipment.
Welding booth with exhaust fans.
Lifting cables, chairs and slings (various sizes and lengths).

District or Division Shop

Torque wrenches.
Impact wrenches.
Socket wrench sets, ¼ in, ½ in and 1 in drive.
Combination box and open end wrenches.
Ignition point wrenches.

Pipe wrenches—6 in to 36 in.
Set of thickness gages 10 in long—0.002 to 0.050.
Set of thickness gages 4 in long—0.002 to 0.050.
Heavy-duty wheel, sprocket and gear pullers.
Heavy duty spanner and ring wrenches—T.
Taps and dies, national coarse and national fine.
Drills of all sizes.
Screw extractors, all sizes.
Stud removers, all sizes.
Screw clamps—1 in to 12 in.
Taper pin reamers.
Taper motor car wheel reamers.
Expansion reamers for bushing ½ in to 2 in, with line reaming extensions.
Gasket punch set.
Flanging tool, ⅛ in to ¾ in, for copper tubing.
Hand tachometer.
Electric tachometer.
Circular hole saws—⅝ in to 3 in.
Gasoline blow torch.
¼-in electric drill.
½-in electric drill with bench stand.
Work benches with 4-in and 6-in vises.
Air compressor, portable.
Snap ring removers.
Garage type dolly jacks.
Anti-freeze tester.
Soldering irons.
Soldering torch for radiator repairs.
Soldering acid gun.
Radiator test tank and rubber ball test plugs.
Air reduction valve for testing radiators.
Hand bolt cutters and nippers.
Bevel protractor and combination square set.
Device for testing air compressors and air tools.
Automotive floor jacks.
Transmission jacks.
Portable hoists.
Bench grinder—8 in.
Starter repair tools.
Safety cleaning vat.
Cylinder ridge reamer.
Cylinder hone
Cylinder sleeves pullers.
Piston vise.
Piston ring measuring tool.
Piston ring compressors.
Piston ring groove cleaners.
Piston pin bushing reamers.
Connecting rod aliner.

Motor repair stand.
Spark plug cleaner and tester.
Spark plug gap gage.
Complete set of spark plug taps.
Valve seat grinder.
Valve seat inserter.
Valve refacer.
Valve guide removers and installers.
Valve guide reamers.
Valve spring lifters.
Hand valve grinder.
Electric valve grinder.
Valve spring tension tester.
Set of carburetor repair tools.
Compression tester.
Fuel pump tester.
Vacuum gage.
Headlight tester and adjuster.
Pressure lubricating unit.
Brake bleeder and filler.
Brake cylinder hone.
Timing light.
Ampere, volt and resistance tester.
Cam angle meter.
Armature growler.
Armature turning and undercutter.
Armature bearing pullers.
DC ammeters (0 to 6 amp and 6 to 30 amp).
DC voltmeter (0 to 150 and 0 to 300).
AC and DC tong tester (0 to 30 amp and 0 to 600 amp).
Brush spring tension scale.
Storage battery analyzer.
Battery terminal cleaner.
Battery cell tester.
Hydrometer for battery acid test.
Battery carrying straps.
Armature dressing stones.
Starter current indicator.
Tube vulcanizing kit.
Tubeless tire repair kit.
Motor car wheel mounting gage.
Motor car wheel thickness gage.
Electric hand saw.
Hydraulic hose connecting and installing equipment.
Portable electric welder—300 amp.
Hydraulic press—50 ton.
Heavy duty pedestal grinder—14 in.
Hydraulic hose cutter.
Manual and hydraulic jacks—10 to 50 ton.

Steam cleaner.
Distributor tester.
Coil and condenser tester.
Test gages for hydraulic pumps and motors.
Battery charger.
Portable chain blocks—¼ to 2 ton capacity.
Motor analyzer kit (automotive).
Oxyacetylene welding and cutting equipment.
Vertical drill press—2-in capacity.
Lathe—10 in, 4-ft centers.
Set of bearing scrapers.
Riveting machine for brake and clutch lining.
Inside and outside micrometers—0 to 6 in.
Inside and outside calipers—0 to 12 in.
Straight edge—36 in.
Steel measuring tape—50 ft.
Electric light extensions.
Brake drum checking gage.
Pipe vises.
Bushing removers and installers.
Overhead or jib cranes.
Lifting cables, chains and slings (various sizes and lengths).
Resonant reed tachometer.
Wheel balancing machine.
Open fire forge, anvil and tools.

Report of Committee 29—Waterproofing

E. A. JOHNSON, *Chairman,*

R. J. BRUESKE,
Vice Chairman,

W. H. ACKER, JR.
A. L. BECKER
D. E. BRAY
LYLE BRISTOW
M. W. BRUNS
W. H. BUNGE
A. E. CAWOOD
G. W. CLARVOE
E. T. FRANZEN
J. M. GILMORE
NELSON HANDSAKER
W. G. HARDING
W. P. HENDRIX
E. K. HERLING
R. L. MAYS
L. H. NEEDHAM
B. J. ORNBURN
H. A. PASMAN
R. A. PETERITAS
MILTON PIKARSKY
R. D. POWRIE
C. W. PRESTON
W. E. ROBEY
JACK SCHMIDT
F. S. SCHUBERT
HENRY SEITZ
T. M. VON SPRECKEN
J. W. WEBER
C. A. WHIPPLE (E)
H. J. WILKINS
K. B. WOODS
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, submitted as information ..... page 469
2. Waterproofing materials and their application to railway structures, collaborating with Committees 6, 8 and 15.
   Progress report, submitted as information ..... page 470
3. Coatings for dampproofing railway structures, collaborating with Committees 6 and 8.
   Progress report, submitted as information ..... page 471

THE COMMITTEE ON WATERPROOFING,
E. A. JOHNSON, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 1

Revision of Manual

R. J. Brueske (chairman, subcommittee), M. W. Bruns, E. T. Franzen, E. A. Johnson, R. L. Mays, C. W. Preston, H. Seitz, T. M. von Sprecken.

This is a progress report, submitted as information.

Your committee is now reviewing the specifications for the purpose of correcting inconsistencies and grammatical errors. The corrections will be submitted for adoption next year, at which time your committee will also recommend for adoption the following revisions in the Specifications for Membrane Waterproofing, Manual pages 29–2–1 to 29–2–13, incl.

On page 29–2–1, Sec. A, Art. 2, add at end of first paragraph: Right-angle bends should be avoided by using rounded or chamfered edges on outside corners and a suitable fillet on inside corners. An underlayment consisting of a bituminous mastic or other suitable material may be placed under the membrane waterproofing on steel deck bridges to protect the membrane against uneven burrs or projections and/or to provide slope for drainage.

On page 29–2–13, Sec. C, Art. 2, Par. f, delete the word "generally" in the ninth line; add a period at the end of this line after the words "375 deg F"; and delete the last two lines.

Report on Assignment 2

Waterproofing Materials and Their Application to Railway Structures

Collaborating with Committees 6, 8 and 15

E. T. Franzen (chairman, subcommittee), W. H. Acker, Jr., R. J. Brueske, A. L. Becker, D. E. Bray, A. E. Cawood, G. W. Clarvoe, N. Handsaker, B. J. Ornburn, H. A. Pasman, R. A. Peteritas, M. Pikarsky, R. D. Powrie, J. Schmidt.

Your committee submits the following progress report as information.

The work on this assignment is progressing on several fronts. For one thing investigation has been completed on a ballast-deck bridge on the Chicago & Western Indiana Railroad to correlate the temperature of the waterproofing membrane to air temperature.

Also, tests of waterproofing membranes continue to be carried on by the AAR research staff in Chicago. Tests have now been completed to determine the qualities and the relation to temperature of various bituminous materials supplied by manufacturers to meet the requirements of AREA specifications for asphalts and tars for above- and below-ground use. Further tests are being made to determine the effect of the number of plies on the quality of the waterproofing membrane. It is anticipated that a report will be made next year on these tests of membranes.

In order to clarify the specifications for membrane waterproofing, your committee is considering changing the words: "insulating paper" to "anti-bonding paper", with the following definitions: "Paper used to prevent bond of membrane. It shall weigh not less than 5 lb per 100 sq ft and be impervious to the bituminous material applied to the membrane."

Consideration is also being given to revising the specifications for asphalt plank and mastic in order to bring these specifications up to date. The basic research on mastic is to be undertaken by Purdue University.

Report on Assignment 3

Coatings for Dampproofing Railway Structures

Collaborating with Committees 6 and 8

C. W. Preston (chairman, subcommittee), L. Bristow, W. H. Burge, J. M. Gilmore, W. G. Harding, W. P. Hendrix, E. K. Herling, L. H. Needham, W. E. Robey, F. S. Schubert, H. Seitz, T. M. von Sprecken, J. W. Weber, H. J. Wilkins, K. B. Woods.

The testing of various properties of dampproofing coatings was continued at Purdue University. The degree to which dampproofing coatings are wet by water is being measured, and the influence of weathering on wetability is being determined.

Film samples made from 14 bituminous emulsions of various types were tested to determine the degree of their wetting by water applied to them. It was found that in a dry state such materials are resistant to the entrance of water into cracks and pinholes, but immersion in water lowers the ability of the material to resist such penetration. Some materials are better than others in this respect. A progress report on this aspect of the work was submitted to the committee.

These emulsion films are also being weathered in an accelerated weathering machine to determine the degree to which their wetting by water is changed by such exposure. Preliminary results indicate that the ability of these materials to withstand penetration of water into imperfections as increased by the weathering process unless the film itself is destroyed.

Silicone films are also being weathered and their wetting characteristics determined. First results show that the ability of these materials to withstand wetting is gradually destroyed by the weathering process until a point is reached where they are probably no longer useful.

The diffusion and permeation of water through intact films of the bituminous emulsion materials are also being determined. These tests show that intact bituminous films are excellent waterproofing materials. It is hoped to be able to characterize the penetration of these films by means of certain thermodynamic properties of the process.

Report of Committee 8—Masonry

E. A. McLeod, *Chairman,*
D. H. Dowe,
Vice Chairman,
J. W. Briscoe
Lyle Bristow
M. W. Bruns
A. E. Cawood
Maurice Coburn (E)
G. W. Cooke
E. J. Daily
H. M. Dalziel
G. H. Dayett
G. H. Dayett, Jr.
J. W. Dolson
B. M. Dornblatt
G. F. Eberly (E)
W. J. Eney
H. J. Engel
J. A. Erskine
J. U. Estes
A. B. Fowler
W. J. Galloway
R. W. Gilmore
J. S. Hancock
G. P. Hayes, Jr.
W. P. Hendrix
A. E. Hotard
A. C. Johnson
E. W. Kieckers
R. J. Klueh
A. P. Kouba
A. N. Laird
E. F. Manley
W. Lyle McDaniel
L. M. Morris
L. H. Needham
L. P. Nicholson
R. F. Noll
M. S. Norris
Roscoe Owen
Donald Patterson
R. E. Paulson
R. B. Peck
J. E. Peterson
C. B. Porter
W. H. Robertson
R. I. Rollings
J. H. Sawyer, Jr.
C. P. Schantz
J. H. Shieber
D. H. Shoemaker
C. H. Splitstone (E)
J. G. Sutherland
Anton Tedesko
R. A. Ullery
L. E. Vandegrift
Neil Van Eenam
K. J. Wagoner
J. W. Weber
C. A. Whipple (E)
J. R. Williams
W. R. Wilson
E. P. Wright
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 474

2. Design of masonry structures, collaborating with Committees 1, 5, 6, 7, 15, 28, 29 and 30.
   Progress report, including recommended revisions of, and additions to, material now in the Manual ..... page 474

3. Foundations and earth pressures, collaborating with Committees 1, 6, 7, 15 and 30.
   Progress in study, but no report.

5. Tunnel linings: Design, construction and maintenance, collaborating with Committees 1, 5, 17, 28 and 29.
   Progress report presented as information and recommended revisions to Manual submitted for adoption ..... page 489

6. Prestressed concrete for railway structures, collaborating with Committee 6.
   Progress in study, but no report.

7. Quality of concrete and mortars, collaborating with Committee 6.
   Progress report, presented as information ..... page 494

10. Methods of construction with precast concrete structural members, collaborating with Committee 6.
Progress in study, but no report.

THE COMMITTEE ON MASONRY,
E. A. MCLEOD, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 1

Revision of Manual

E. P. Wright (chairman, subcommittee), G. H. Dayett, Jr., D. H. Dowe, J. U. Estes, A. C. Johnson, A. P. Kouba, R. B. Peck, R. A. Ullery.

Your committee recommends the adoption of the revisions to the Manual as set forth in the reports on Assignments 2 and 5.

Report on Assignment 2

Design of Masonry Structures

Collaborating with Committees 1, 5, 6, 7, 15, 28, 29 and 30

J. U. Estes (chairman subcommittee), E. J. Daily, H. M. Dalziel, J. S. Hancock, A. N. Laird, D. Patterson, R. E. Paulson, J. H. Shieber, A. Tedesko, L. E. Vandegrift.

Your committee submits the following report recommending the adoption of revisions and additions to certain material now in the Manual.

Pages 8–1–1 to 8–1–26, incl.

SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE RAILROAD BRIDGES AND OTHER STRUCTURES

Page 8–1–6. Change Sec. E, Art. 2. Quality, to read as follows:

2. Quality

All steel reinforcing bars shall be of structural or intermediate grade billet, rail or axle steel, as specified on the drawings.

The material shall conform in quality to the following ASTM Specifications:

Bars: A 15, A 16, A 160
Deformations: A 305
Wire: A 82
Fabricated Materials: A 184, A 185.

When cast iron or srtuctural steel sections are used, as in composite or combination columns, these materials shall conform in quality to the standard ASTM Specifications of the following applicable serial designations: A 7, A 377.

Page 8–1–8. Add to Sec. H, Art. 2. Bending, the following:

Field bending of rail or axle steel shall not be permitted except as approved by the engineer.

Your committee also presents as information a tentative draft of Specifications for Design and Construction of Reinforced Concrete Trestles for Railway Loading, and requests comments and criticisms thereon, with the thought of presenting them next year for adoption and publication in the Manual.

SPECIFICATIONS FOR DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE TRESTLES FOR RAILWAY LOADING

A. GENERAL

1. Definition

A concrete trestle is a bridge structure composed of a series of short concrete spans supported on pile bents.

2. Scope

Trestles constructed under this specification shall be built complete, ready for the laying of track, in strict accordance with the plan and intent of these specifications.

Nothing contained herein shall be construed as superseding details shown on the drawings. Where the specifications conflict with the drawings, the drawings shall govern.

3. Bents

The bents shall consist of three or more piles with a cast-in-place reinforced concrete cap. The piles may be either precast reinforced concrete, concrete-filled tubular steel, or other acceptable types, such as H-piles.

4. Spans

These spans shall be precast reinforced concrete slabs carrying the track on a ballasted deck. Each span shall consist of two parallel slabs abutting each other at the center line of track.

B. DESIGN

1. General

The Specifications for Design of Plain and Reinforced Concrete Members as prescribed in Part 2, this Chapter, shall govern except as otherwise provided herein.

2. Assumptions

The slabs shall be designed as simple spans with each slab carrying the live load from one rail. Direct vertical loads shall be uniformly distributed transversely to the slabs and piles.

The piles shall be assumed fixed at the caps. The bearing of the slabs on the bents shall be assumed not to restrain the rotation or translation of the caps.

The piles shall be designed as columns in accordance with Part 2, but in addition they shall be designed for handling as shown on Fig. 8.

3. Design Loads

The following loads shall be used in the design of concrete trestles:

a. Dead load
b. Live load
c. Impact
d. Centrifugal force
e. Lateral forces
f. Longitudinal forces

4. Dead Load

The dead load shall consist of the estimated weight of the track, ballast and the structural member. Dead-load moments and shears are shown on Fig. 6 for slab spans 14 ft to 22 ft, incl.

5. Live Load

The recommended live load shall be Cooper E 72. Live-load moments and shears are shown on Fig. 6 for slab spans 14 ft to 22 ft, incl.

6. Impact

Impact forces shall be distributed to the slabs as for the live load. Impact moments and shears are shown on Fig. 6 for slab spans 14 ft to 22 ft, incl.

Impact forces shall be distributed to the bents in accordance with the formula

$$I = \frac{100L}{L + D} ,$$

where I is the percentage of the live load for impact, L is the live-load bent reaction and D is the dead-load bent reaction.

Impact shall be neglected in determining the bearing capacity of the pile (see Part 4, Pile Foundations this Chapter).

7. Centrifugal Force

Centrifugal force as a percentage of the live load shall be determined as indicated in Part 2, this Chapter.

8. Lateral Forces

Lateral forces shall be determined as indicated in Part 2.

9. Longitudinal Forces

The magnitude of the longitudinal forces shall be in accordance with Part 2.

For trestles not exceeding 200 ft in length, having longitudinal continuity by frictional resistance and having no open rail joints, the entire longitudinal force may be considered carried to the embankments at the end of the trestle. For trestles exceeding 200 ft having continuity of members, no open rail joints and double bents, as shown on Fig. 1, one-half the specified longitudinal force shall be distributed to the bents in proportion to their relative stiffnesses.

If longitudinal continuity is broken, as by a movable span or a span having expansion bearings, the entire longitudinal force shall be distributed to the bents (or piers) in proportion to their relative stiffnesses.

C. CONSTRUCTION

1. General

The general construction is shown on Fig. 1. Selection of span lengths will generally be influenced by the location of existing timber bents and other local conditions.

2. Precast Concrete Piles

Details of 24-in precast octagonal piles are shown on Fig. 8 for lengths up to 60 ft. Pick-up points for handling shall be clearly marked as shown. The pile may be picked up at either or both points, as indicated.

The piles shall be manufactured, handled and driven in compliance with Part 4, this Chapter. They shall be driven to a working load of 75 tons per pile. Loading tests, when required, shall comply with Part 4.

3. Precast Prestressed Concrete Piles

Details of 21-in prestressed square piles are shown on Fig. 11 for lengths up to 94 ft. Pick-up points for handling shall be clearly marked as shown. The pile may be picked up at either or both points (see note on Fig. 11).

The piles shall be manufactured, handled and driven in compliance with Part 4. They shall be driven to a working load of 75 tons per pile. The stress in the concrete due to prestress is 800 psi to reduce the rebound effect during driving. Loading tests, when required, shall comply with Part 4.

4. Cast-In-Place Concrete Piles

Tubular-steel, concrete-filled piles may be used in lieu of precast concrete piles. Details of typical bent construction using these piles are shown on Fig. 9. The piles shown may be of either fluted or plain section. The plain round piles shall be seamless or butt seam welded tubes. Piles shall be driven in compliance with Part 4. They shall be driven to a working load of 75 tons per pile. Loading tests, when required, shall comply with Part 4.

5. Steel H-Piles

Steel H-piles may be used in lieu of precast concrete piles. Details of typical bent construction using these piles are shown on Fig. 10.

Piles shall be driven in compliance with Part 4. They shall be driven to a working load of 75 tons per pile. Loading tests, when required, shall comply with Part 4.

6. Bents

The piles in each bent may be driven by shifting the bridge ties with little or no disturbance to the existing structure. The center pile may be driven between the stringers and the other piles driven outside the stringers.

The caps and collars for the single and double bents shall be cast in place. The portion of the double bents between slabs above the bridge seat, as shown on Fig. 5, shall be cast in place after the stringers have been removed and the slab erected. Details of single and double intermediate bents are shown on Fig. 3, and details of end bents are shown on Fig. 4.

7. Spans

Fig. 6 shows typical details of precast slabs for spans of 14 to 22 ft, incl. The depth of slabs for these spans may be held constant at 2 ft, or varied as shown in the tables.

Fig. 7 shows details of drainage. The joint between the slabs at the center line of track and over the bents is covered with 1 by 8-in asphalt planks to permit relative movements of the slabs and retain the ballast.

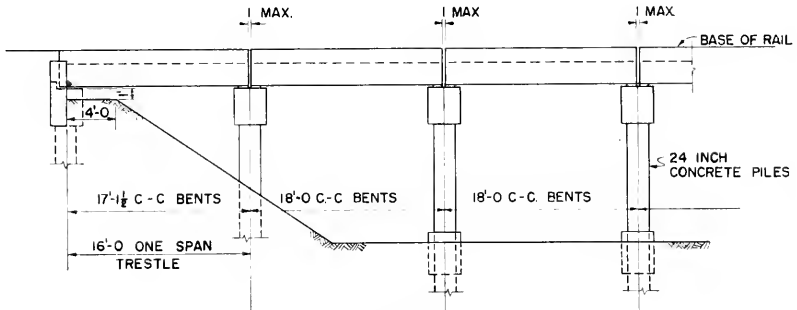
If it is objectionable to discharge deck drainage through the slab as shown, the deck drains may be eliminated, the entire ballast trough waterproofed with a membrane as described in Art. 8, following, and the drainage carried to intermediate points for disposal through downspouts. If drainage is carried to the end of the trestle, perforated pipe may be laid behind the end bent back wall and wingwalls for disposal down the embankment slope.

8. Waterproofing

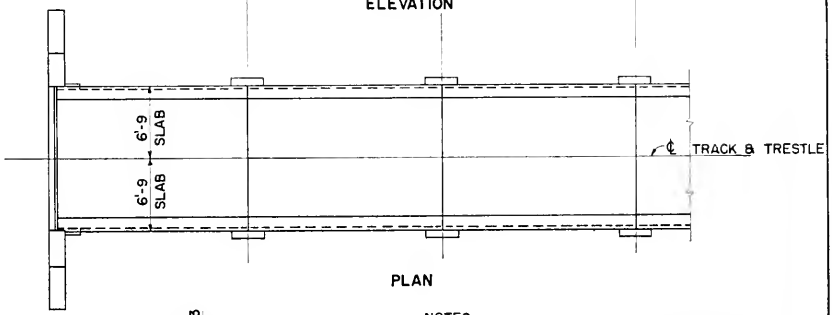
When required, the ballast trough shall be waterproofed by applying a three-ply membrane and a protective cover to the surfaces as specified in Part 2, Chapter 29. This membrane shall be type C, consisting of two layers of bitumen-treated felt, one middle layer of bitumen-treated cotton fabric and four moppings of bitumen. The protective cover shall be asphalt plank.

FIG. 1
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

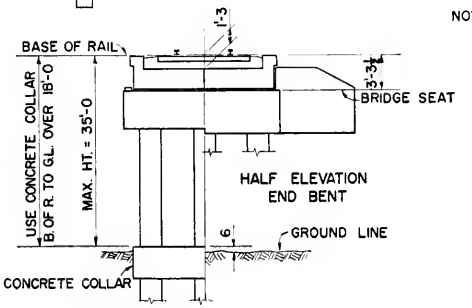
GENERAL PLAN



ELEVATION



PLAN



NOTES:

LENGTH AND DEPTH OF SLABS MAY VARY, SEE FIG. 5. SLAB SHOWN IS 17'-11 DEPTH IS 2'-0.
FOR GENERAL NOTES SEE FIG. 2.
FOR HEIGHTS OVER 35 FT. BENTS SHALL BE DESIGNED IN ACCORDANCE WITH PART 2 OF CHAPTER 8.

BENTS WITH THREE 24" CONCRETE PILES CAPABLE OF RESISTING 10 % OF THE SPECIFIED LONGITUDINAL FORCE FOR THE TWO ADJACENT SPANS AS REQUIRED IN PART 2-C OF CHAPTER 8.

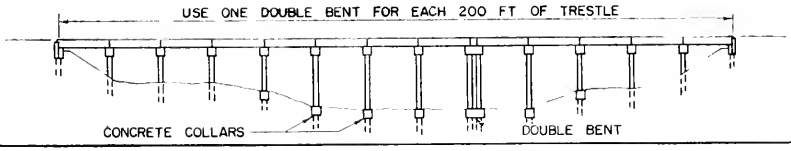


FIG. 2. AMERICAN RAILWAY ENGINEERING ASSOCIATION CONCRETE RAILWAY TRESTLE GENERAL NOTES

All concrete and concrete work shall conform to the appropriate specifications in Chapter 8, AREA Manual, and AREA Instructions for Mixing and Placing Concrete, 1952.

Ultimate compressive strength of concrete shall be not less than 4000 psi in 28 days with the maximum water-cement ratio specified in Chapter 8, Part 1, Sec. J, Table 1, for the condition of exposure to which it will be subjected.

Reinforcement shall conform to specifications in Part 1. Reinforcement areas shown are based on 20,000 psi.

Where bars are shown on the drawings to be spliced, they shall be lapped a minimum of 24 diameters.

The reinforcement shall have a minimum cover of 2 in of concrete, unless otherwise indicated on the drawings.

All reinforcement shall conform with the detail drawings.

Construction joints shall be wire-brushed before the concrete has hardened, or have all laitance completely removed by picks, chisels or other means. Dirt and other foreign material must be thoroughly cleaned off and surfaces dampened before additional concrete is placed.

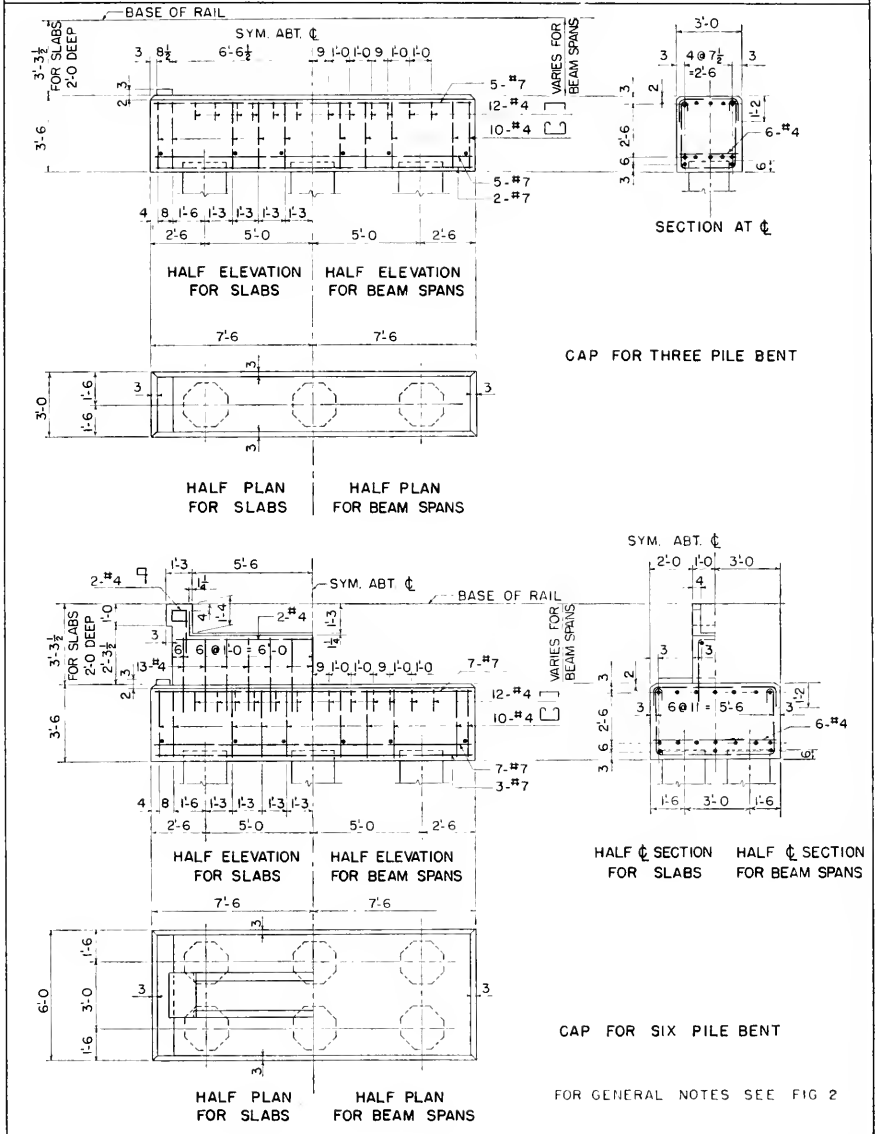
Concrete above and below construction joints shall be cast monolithically.

Construction joints shall be located only as shown on the drawings.

Concrete piles shall be precast to the dimensions shown on the drawings. They shall be driven to refusal or 75 tons capacity as determined from load tests described in Part 4, Chapter 8. The pile capacity shall include dead load plus live load without impact.

FIG 3
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

INTERIOR BENTS



FOR GENERAL NOTES SEE FIG 2

FIG 4
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

END BENTS

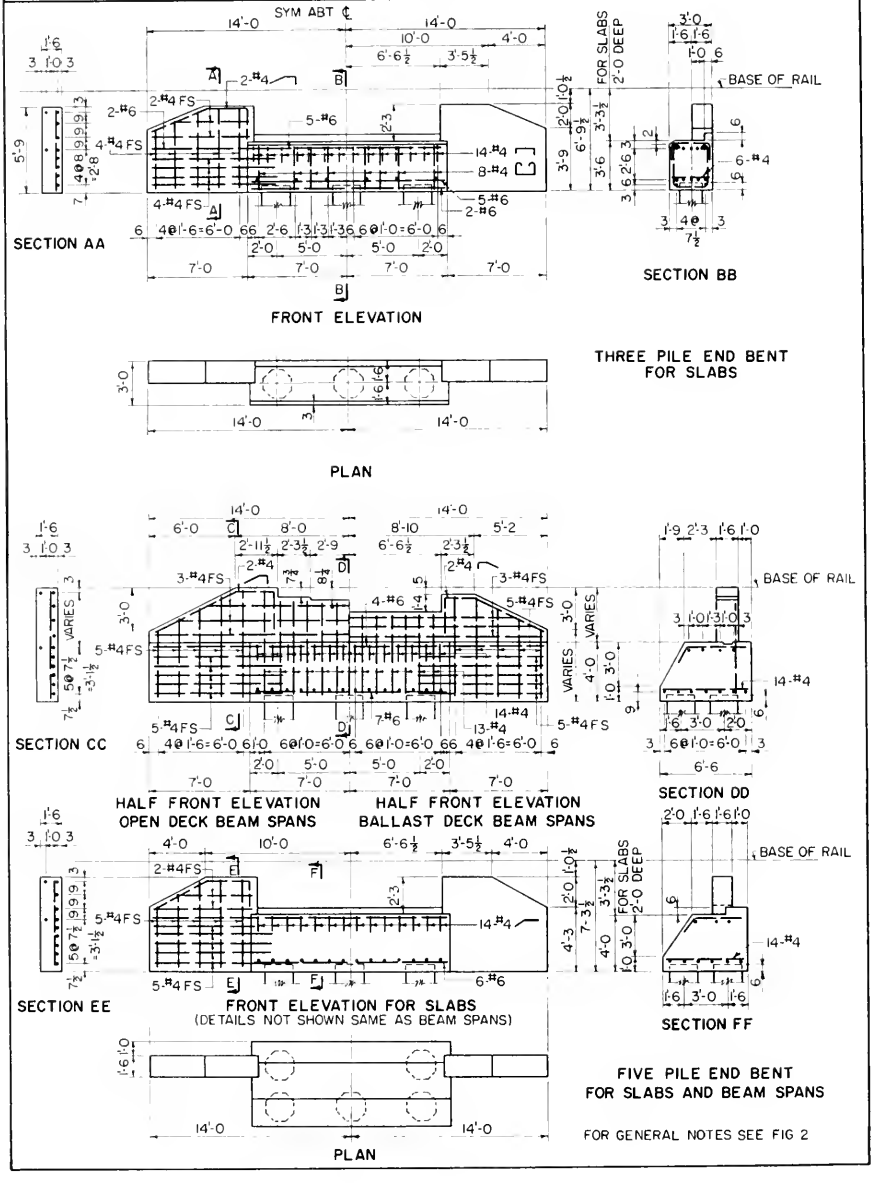
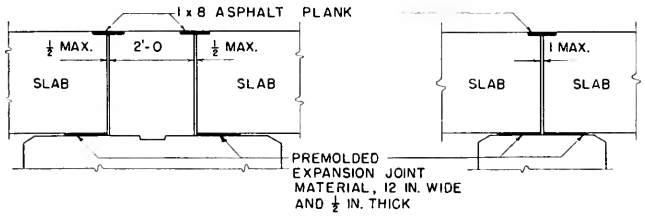


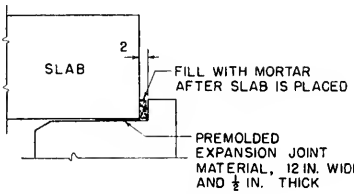
FIG. 5
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

MISCELLANEOUS BENT DETAILS

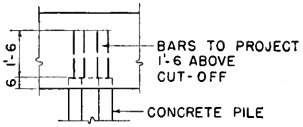


SLAB JOINT DETAIL
SIX PILE BENT

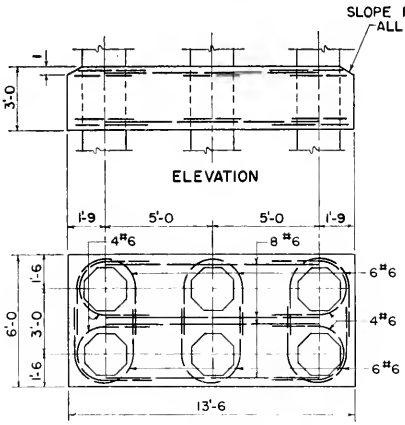
SLAB JOINT DETAIL
THREE PILE BENT



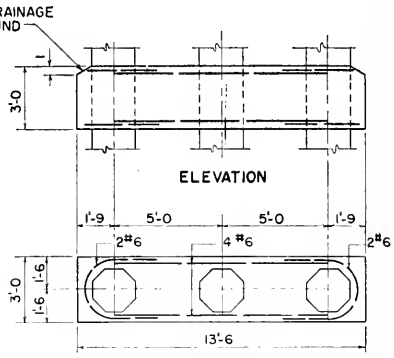
END BENT BEARING DETAIL



DETAIL AT TOP OF PILE



COLLAR FOR SIX PILE BENT

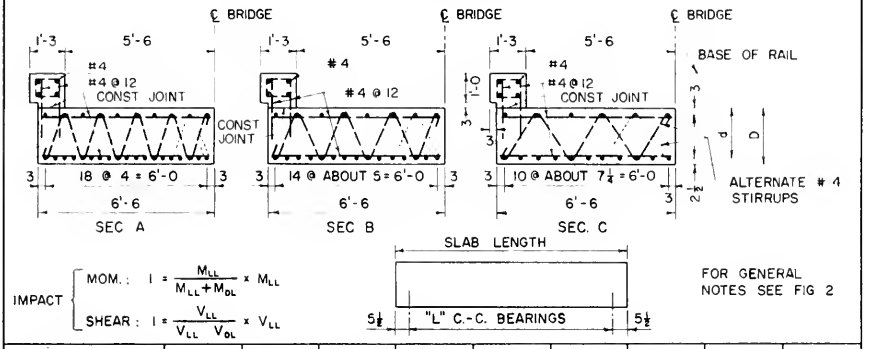


COLLAR FOR THREE PILE BENT

FOR GENERAL NOTES SEE FIG. 2

FIG. 6
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

SLAB DESIGN AND DETAILS



SPAN L FEET	22	21	20	19	18	17	16	15	14
MOMENTS - FT. KIPS FOR ONE RAIL									
DL 3.05 K/FT	184.5	168.2	152.5	137.8	123.5	110.2	97.6	85.8	74.7
LL E 72	442.2	406.7	371.2	335.8	306.0	279.0	252.0	225.0	198.0
I	312.0	288.0	263.0	238.0	218.0	200.0	181.8	162.9	143.6
TOTAL	938.7	862.9	786.7	711.6	647.5	589.2	531.4	473.7	416.3
SHEAR - KIPS FOR ONE RAIL									
DL 3.05 K/FT	33.6	32.0	30.5	29.0	27.4	25.9	24.4	22.9	21.4
LL E 72	94.9	92.6	90.0	87.2	84.0	80.5	76.5	72.0	69.4
I	70.1	68.9	67.2	65.5	63.3	60.9	58.1	54.6	53.0
TOTAL	198.6	193.5	187.7	181.7	174.7	167.3	159.0	149.5	143.8

TABLE I - DEPTH VARIES (IDEAL SECTION)

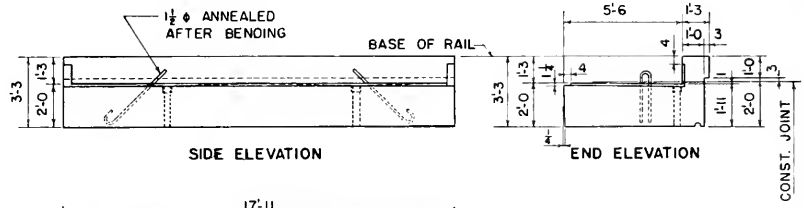
"L" FEET	SEC.	D INCHES	d INCHES	TENS STEEL A_s REQD.	TENS ST. FURN, f_s IN KSI	COMP STEEL A'_s REQD	LONG ST FURN f'_s IN KSI	CONCRETE f_c IN PSI	STIRRUP SPACING FROM EACH END
22	A	24	21½	30.3 SQ IN	19-#11, 20.3	0	10-#5, 16.2	1670	7 @ 10
21	A	23	20½	29.3 "	19-#11, 19.8	0	10-#5, 15.9	1670	7 @ 10
20	A	22	19½	28.0 "	19-#11, 18.9	0	10-#5, 15.4	1640	7 @ 10
19	A	21	18½	26.7 "	19-#11, 18.1	0	10-#5, 14.9	1630	8 @ 8
18	A	20	17½	25.7 "	19-#11, 17.4	0	10-#5, 14.5	1620	8 @ 8
17	A	19½	17	24.0 "	19-#10, 19.9	0	10-#5, 13.9	1660	7 @ 8
16	A	18½	16	23.1 "	19-#10, 19.2	0	10-#5, 13.6	1670	7 @ 8
15	B	17½	15	21.9 "	15-#11, 19.0	0	8-#5, 13.2	1680	9 @ 6
14	B	16½	14	20.6 "	15-#11, 17.8	0	8-#5, 12.5	1670	9 @ 6

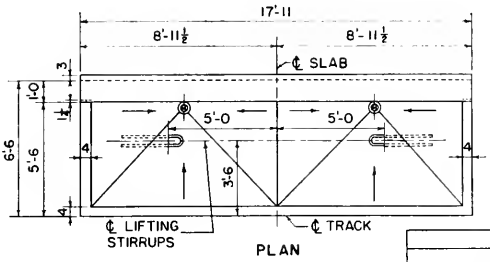
TABLE II - CONSTANT DEPTH

"L" FEET	SEC	D INCHES	d INCHES	TENS STEEL A_s REQD	TENS. ST. FURN f_s IN KSI	COMP. STEEL A'_s REQD	LONG. ST FURN. f'_s IN KSI	CONCRETE f_c IN PSI	STIRRUP SPACING FROM EACH END
22	A	24	21½	30.3 SQ. IN	19-#11, 20.3	0	10-#5, 16.2	1670	7 @ 10
21	A	24	21½	27.9 "	19-#11, 18.8	0	10-#5, 15.1	1550	6 @ 10
20	A	24	21½	25.3 "	19-#10, 20.6	0	10-#5, 13.8	1490	5 @ 10
19	B	24	21½	23.0 "	15-#10, 19.4	0	8-#5, 12.7	1380	5 @ 10
18	B	24	21½	20.9 "	15-#11, 17.7	0	8-#5, 11.6	1250	4 @ 10
17	B	24	21½	19.0 "	15-#10, 19.4	0	8-#5, 10.7	1220	4 @ 10
16	C	24	21½	17.1 "	11-#11, 19.6	0	6-#5, 9.5	1130	3 @ 10
15	B	24	21½	15.3 "	15-#9, 19.6	0	8-#5, 8.7	1070	2 @ 10
14	C	24	21½	13.4 "	11-#10, 18.5	0	6-#5, 7.9	980	1 @ 10

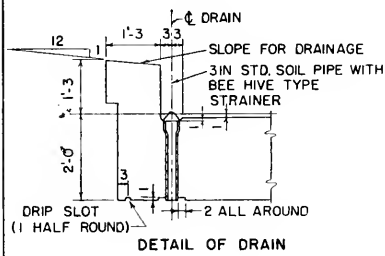
FIG. 7
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

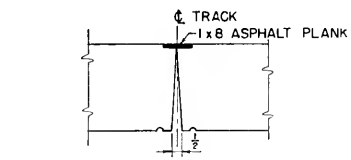
MISCELLANEOUS SLAB DETAILS





NOTES:
LENGTH AND DEPTH OF SLABS MAY VARY, SEE FIG. 6 SLAB SHOWN IS 17'-11, DEPTH IS 2'-0
FOR GENERAL NOTES SEE FIG. 2

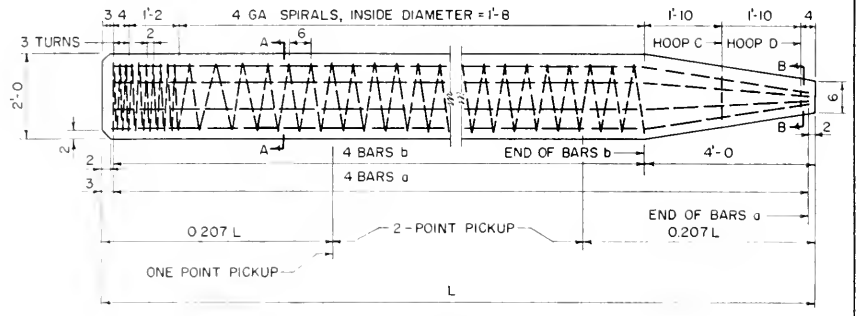




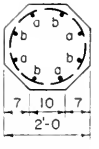
QUANTITIES			
DETAIL		CONCRETE CU. YDS.	REINF. STEEL LBS.
END BENTS			
SLABS	3 PILE	10.0	531
SLABS	5 PILE	15.9	460
BEAM SPANS	OPEN DECK	19.8	606
BEAM SPANS	BALLASTED DECK	20.6	607
INTERIOR BENTS			
SLABS	3 PILE CAP	5.6	466
SLABS	3 PILE COLLAR	3.4	111
SLABS	6 PILE CAP	13.4	662
SLABS	6 PILE COLLAR	6.8	375
BEAM SPANS	3 PILE CAP	5.6	466
BEAM SPANS	3 PILE COLLAR	3.4	111
BEAM SPANS	6 PILE CAP	11.2	560
BEAM SPANS	6 PILE COLLAR	6.8	375
SPANS			
DEPTH VARIES	14'-0 SLABS	5.7	1695
DEPTH VARIES	15'-0 "	6.4	1838
DEPTH VARIES	16'-0 "	7.1	1980
DEPTH VARIES	17'-0 "	7.9	2270
DEPTH VARIES	18'-0 "	8.6	2560
DEPTH VARIES	19'-0 "	9.5	2685
DEPTH VARIES	20'-0 "	10.3	2810
DEPTH VARIES	21'-0 "	11.3	2945
DEPTH VARIES	22'-0 "	12.3	3080
CONSTANT DEPTH	14'-0 "	8.0	1110
CONSTANT DEPTH	15'-0 "	8.4	1250
CONSTANT DEPTH	16'-0 "	9.0	1453
CONSTANT DEPTH	17'-0 "	9.6	1762
CONSTANT DEPTH	18'-0 "	10.1	2070
CONSTANT DEPTH	19-0 "	10.7	2253
CONSTANT DEPTH	20'-0 "	11.2	2400
CONSTANT DEPTH	21'-0 "	11.7	2713
CONSTANT DEPTH	22'-0 "	12.3	3080

FIG 8
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

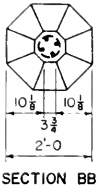
24 INCH CONCRETE PILE



ELEVATION



SECTION AA



SECTION BB

LENGTH OF PILE	BAR SIZE	LONGITUDINAL REINFORCEMENT BAR "a" NO.	BAR "a" LENGTH	BAR "b" NO.	BAR "b" LENGTH
0'-0 TO 29'-0 INCL.	#5	4	L-0'-5	4	L-4'-3
30'-0 TO 33'-0 INCL	#6	4	L-0'-5	4	L-4'-3
34'-0 TO 39'-0 INCL	#7	4	L-0'-5	4	L-4'-3
40'-0 TO 44'-0 INCL.	#8	4	L-0'-5	4	L-4'-3
45'-0 TO 49'-0 INCL	#9	4	L-0'-5	4	L-4'-3
50'-0 TO 55'-0 INCL.	#10	4	L-0'-5	4	L-4'-3
56'-0 TO 60'-0 INCL.	#11	4	L-0'-5	4	L-4'-3

USE 4 GA. FOR HOOPS
HOOP C, I.D. = 1'-1
HOOP D, I.D. = 6

DESIGN OF PILE FOR HANDLING

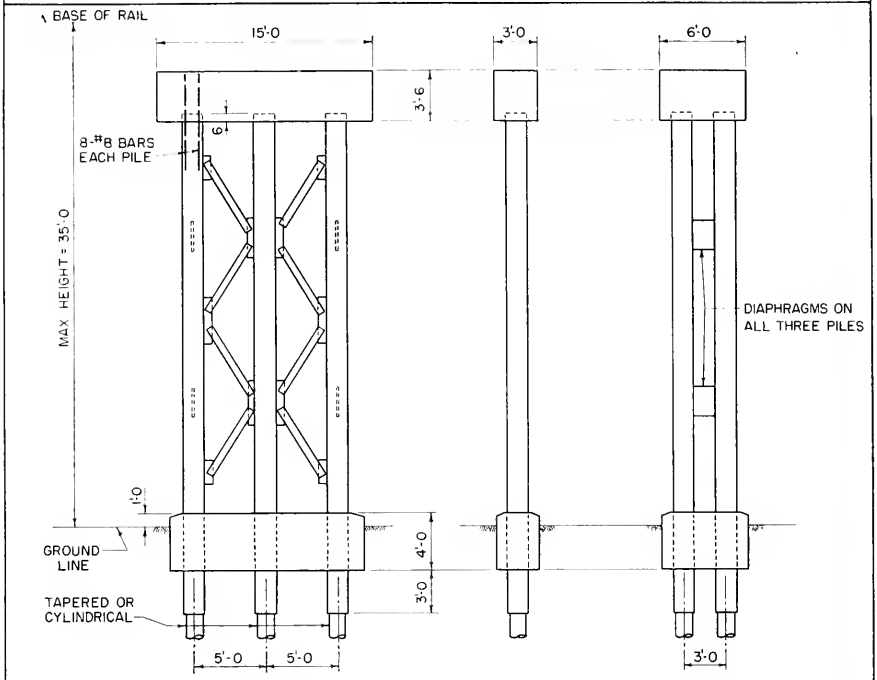
TWO-POINT PICKUP
CONCRETE STRESS, f_c = 1080 PSI
STEEL STRESS, f_s = 12,000 PSI
IMPACT, 100 %

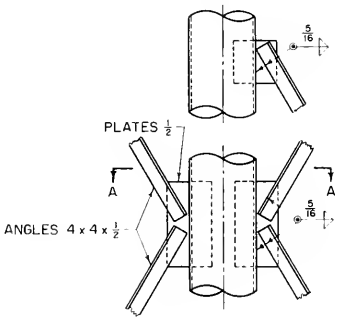
NOTE:
WHEN PILE IS PICKED UP AT ONE POINT AS MARKED,
MAX f_s = 24,000 PSI
MAX f_c = 2160 PSI
IMPACT, 25 %

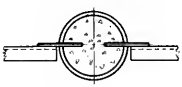
FOR GENERAL NOTES SEE FIG. 2

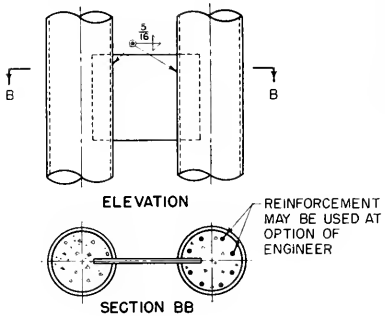
FIG 9
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

18 INCH TUBULAR STEEL CONCRETE FILLED PILES





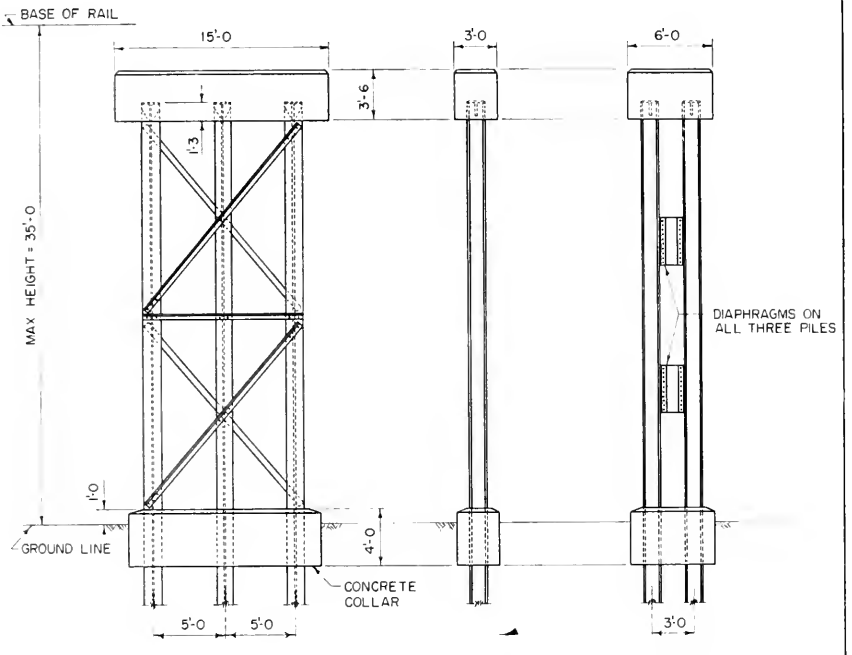


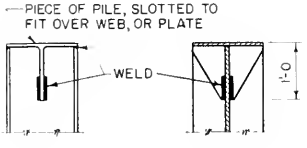


NOTES
MINIMUM WALL THICKNESS FOR PILES - 3 GAGE.
STRENGTH OF CONCRETE IN PILES, f'_c = 6,000 PSI.
FOR BASE OF RAIL TO GROUND LINE LESS THAN 16'-0, OMIT TRANSVERSE BRACING AND COLLAR
CAP AND COLLAR DETAILS SIMILAR TO FIGS. 3 AND 5
THREE PILE BENTS DESIGNED FOR 10% OF THE SPECIFIED LONGITUDINAL FORCE FOR THE TWO ADJACENT SPANS AS REQUIRED IN PART 2-C OF CHAPTER 8.

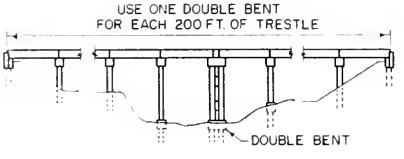
FIG. 10
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

STEEL H-PILE BENT





PILE CAP DETAIL



NOTES.
IF BASE OF RAIL TO GROUND LINE IS 16'-0 OR LESS, USE 14BP117 WITHOUT TRANSVERSE BRACING AND COLLAR OR 14BP102 WITH BRACING AND COLLAR

FOR BASE OF RAIL TO GROUND LINE 35'-0, USE 14BP117 WITH BRACING AND COLLAR.

FOR BASE OF RAIL TO GROUND LINE LESS THAN 21'-0, USE ONE PANEL TRANSVERSE BRACING. FOR BASE OF RAIL TO GROUND LINE GREATER THAN 21'-0, USE TWO PANEL TRANSVERSE BRACING.

USE L$5 \times 3 \times \frac{3}{8}$ OR 8⌴18.75 FOR TRANSVERSE BRACING.

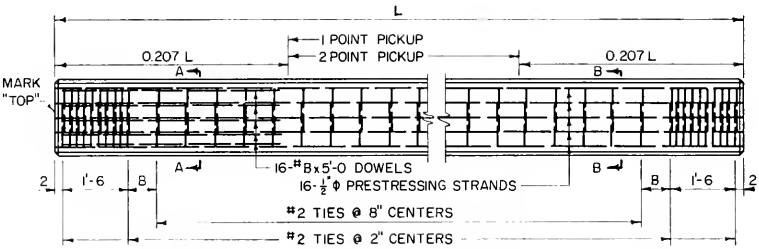
USE $\frac{7}{8}$" HIGH STRENGTH BOLTS WITH HEAVY NUTS CONFORMING TO ASTM DESIGNATION A325 OR $\frac{1}{4}$" FILLET WELDS FOR ALL BRACING CONNECTIONS.

CONCRETE CAP AND COLLAR DETAILS SIMILAR TO FIGS 3 AND 5

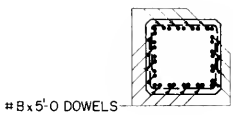
THREE PILE BENTS DESIGNED FOR 10% OF THE SPECIFIED LONGITUDINAL FORCE FOR THE TWO ADJACENT SPANS AS REQUIRED IN PART 2-C, CHAPTER 8

FIG. 11
AMERICAN RAILWAY ENGINEERING ASSOCIATION
CONCRETE RAILWAY TRESTLE

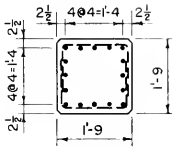
21 INCH PRESTRESSED CONCRETE PILE



ELEVATION



SECTION AA



SECTION BB

NOTES

ALL PRESTRESSING STRANDS SHALL BE ½ϕ, 7 WIRE UNCOATED, STRESS-RELIEVED, MEETING THE REQUIREMENTS OF ASTM DESIGNATION A416, WITH A MINIMUM BREAKING STRENGTH OF 36,000 LB PER STRAND.
INITIAL PRESTRESS SHALL BE 27,000 LB PER STRAND.
DOWELS SHALL BE INTERMEDIATE GRADE DEFORMED BARS MEETING THE REQUIREMENTS OF ASTM DESIGNATIONS A15 AND A305.
TIES SHALL BE INTERMEDIATE GRADE BARS MEETING THE REQUIREMENTS OF ASTM DESIGNATION A15.
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE SHALL BE NOT LESS THAN 6,000 PSI IN 28 DAYS
CHAMFER ALL EDGES 1"
MAXIMUM LENGTH OF PILE = 50' FOR NO TENSION IN CONCRETE DUE TO HANDLING OR 66' FOR CRACKING MOMENT DUE TO HANDLING (CRITICAL HANDLING LOAD IS ONE POINT PICKUP WITH 25% IMPACT)
DOWELS PROVIDED IN TOP OF PILE MAY BE USED FOR ANCHORAGE INTO CAPS AS SHOWN ON FIGURE 5 FOR SPLICING ON ADDITIONAL LENGTH.

Report on Assignment 5

Tunnel Linings: Design, Construction and Maintenance

Collaborating with Committees 1, 5, 17, 28 and 29

G. H. Dayett, Jr. (chairman, subcommittee), R. J. Klueh, C. B. Porter, D. H. Shoemaker, L. H. Needham.

Your committee submits the following report in two parts. Part 1 is a bibliography on tunnel repairs, submitted as information; Part 2 presents recommendations for revisions in the Manual for adoption.

Part 1—Bibliography on Tunnel Repairs

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2. "It's a Brand New Construction Job Every Night in the Holland Tunnel" (Repair after fire), Engineering News Record, July 21, 1949, p. 32.

3. "Tunnel Trouble & How to Correct It", by W. W. Morrison and Elwin E. Seelye, Railway Age, Feb. 22, 1947, Vol. 122, p. 412.

4. "B&O Repairs Kingwood Bore by Novel Method" (Drift over old arch and repaired from above), Railway Age, June 29, 1946, Vol. 120, p. 1258.

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1. "Railways of Britain Carry On", The Sphere, London, England, Juyl 26, 1941, p. 110.

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2. Grouting of Railroad Structures, Committee 8—Masonry, Appendix 1—"Pressure Grouting (Tunnels)", AREA Proceedings, Vol. 41, 1940, p. 390.

3. "Tunnel Lining Surgery, Atchison, Topeka & Santa Fe Ry.", Compressed Air (Trade Journal), March 1938, Vol. 43, p. 5561–5564.

3 (a). Amplification of above, by M. C. Blanchard (A Report to AREA Committee 8—Masonry), Proceedings, Vol. 41, 1940, p. 399.

4. "Restore Concrete Tunnel Lining by Intrusion Process", by F. D. Kinnie, Railway Age, March 4, 1939, Vol. 106, p. 373.

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2. "Inside Looking Out", Western Pacific Niles Tunnel, Relining, Mile Posts, Western Pacific Magazine, Jan. 1955, p. 3.

3. "W. P. Upgrades Tunnels, Replaces Wood Lining with Concrete", Modern Railroads, March 1955, p. 115.

4. "Precast Rings Eliminate Shoring" (Mt. Rainer National Park Highway Tunnel), Engineering News Record, Dec. 22, 1955, p. 30.

5. "Chilcoot Tunnel Gets a New Look", Mile Posts, Western Pacific Magazine, Aug. 1954, p. 3.

6. "Tunnel Linings with Special Reference to a New Form of Reinforced Concrete Lining," (Abstract of a paper read before the Institution of Civil Engrs. Feb. 9, 1943—Precast & Reinforced Tunnel Lining Segments), The Railway Gazette (London), March 19, 1943, Vol. 78, p. 303.

7. "Denver and Salt Lake Seeks Greatest Security Through Long-Time Tunnel Lining Program", Railway Engineering & Maintenance, Oct. 1942, p. 692.

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9. "Denver & Salt Lake Lines Moffat Tunnel with Concrete", Railway Age, Nov. 16, 1935, p. 626.

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1. Tunnel Scrubber (Highway Tunnel), Engineering News Record, April 18, 1957, p. 94.

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2. "Enlarging & Relining, also Rib Design" (SP Co.) Railway Age, 1948, p. 678.

3. "Effective Methods are Employed In Enlarging Tunnels on C&O", Railway Age, Nov. 12, 1932, Vol. 93, p. 665.

Lowering Track

1. "To Get More Clearance, Undercuts Track in Tunnel, N & W—Stone coal to Welch W. Va.", Railway Track & Structures, March 1955, Vol. 51, p. 66.

2. "Lowering a Rock Tunnel Floor—Del. & Hudson R. R. Lowered Floor Av. of 2 Ft to Get Clearance", Railway Gazette (London), & Railway Engineering and Maintenance, Oct. 8, 1943, Vol. 79, p. 360; June 1943, p. 440.

3. "Care & Precision Feature Rebuilding of Tunnel Floor" (C&O Increases Vertical Clearance by Constructing Concrete Slab at Lower Level), Railway Age, Jan. 9, 1937, Vol. 103, p. 116.

Part 2—Revision of Specifications for Lining Tunnels with Timber

Your committee offers the following recommendations with respect to the Manual:

Pages 8–11–13 to 8–11–17, incl.

SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH TIMBER

Reapprove with the following revisions:

Page 8–11–13. Delete Art. 4 and replace with the following:

4. Timber—Treatment

The preservative and treatment shall be in accordance with current specifications in Chapter 17.

Page 8–11–15. Delete the first paragraph under Art. 20. Allowance for Settlement.

Page 8–11–16. Delete Fig. 1 and replace with new Fig. 1 presented herewith.

Page 8–11–17. Delete Fig. 2 and replace with new Fig. 2 presented herewith.

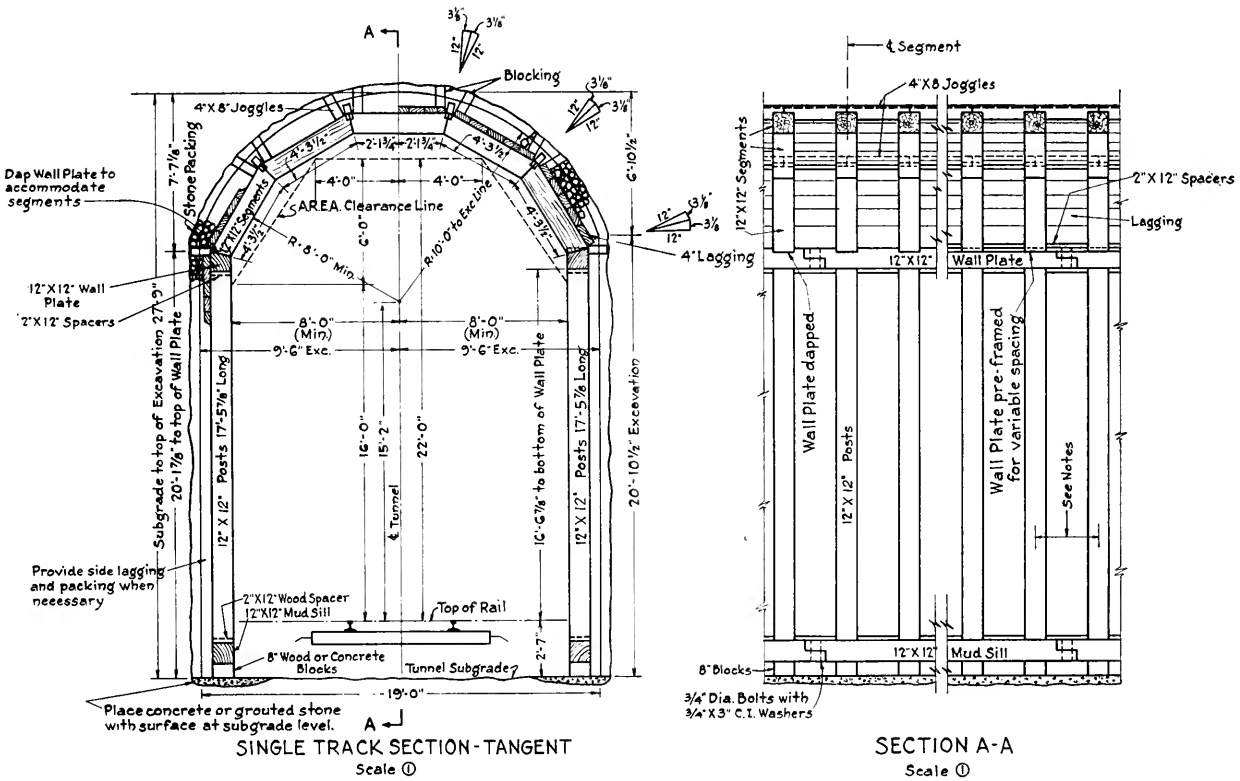
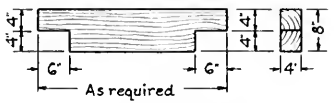


Fig. 1—Details of timber lining for tunnel.



TYPICAL JOGGLE
Scale ②

NOTES

Blocking is to be used at all segment joints.

Spacing of Posts shall be specified by the Engineer but shall not exceed 6'-0"

On double track where centers are more than 13 feet, increase distance between sidewalls accordingly. On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 85 feet long, 60 feet between centers of trucks and 14 feet high. The superelevation of the outer rail shall be in accordance with the recommended practice of the A.R.E.A.

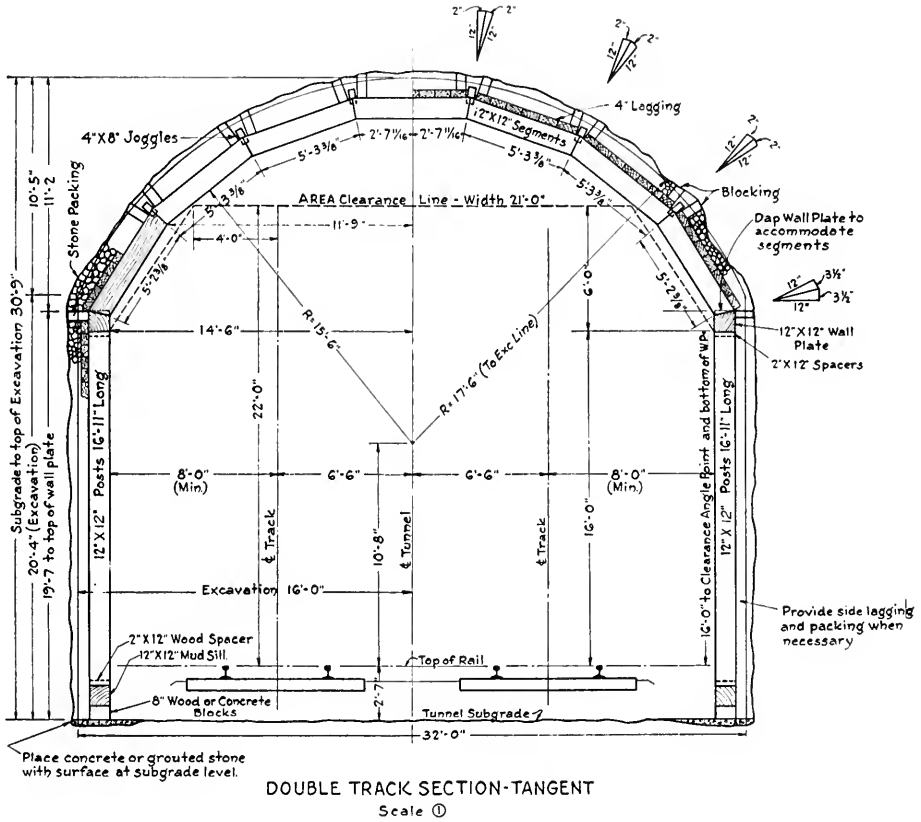
Provide additional width or make other provision for drainage as conditions require.

A concrete foundation may be used in place of the timber sill and mud blocks. All joints other than those shown with fastenings shall be fastened as directed by the engineer.

SCALE

① 0 2 4 8 Feet

② 0 12 24 32 Inches



DOUBLE TRACK SECTION-TANGENT
Scale ①

Fig. 2—Details of timber lining for tunnel.

Report on Assignment 7

Methods for Improving the Quality of Concrete and Mortars

Collaborating with Committee 6

R. A. Ullery (chairman, subcommittee), Lyle Bristow, M. W. Bruns, W. J. Galloway, L. M. Morris, L. P. Nicholson, M. S. Norris, J. G. Sutherland.

Your committee submits as information the following report on the use of fly ash in concrete.

Use of Fly Ash in Concrete

Since 1930 the use of fly ash either as an admixture or as a replacement for cement has become more extensive each year. Research and tests have been conducted by universities, government agencies and by industrial organizations, with various results.

What is Fly Ash

Wherever pulverized coal is used for fuel, a considerable percentage of the ash rises into the stack with the gases of combustion. This substance, in the form of a very fine powder, is called fly ash. Fly ash is a waste product of combustion and is comprised largely of spherically shaped, smooth, glassy particles having a fineness about equal to or finer than portland cement. In modern plants it is collected at the entrance to the stack by electric precipitators. Originally removed to avoid pollution of the outside air, fly ash was later found to be useful as a building material.

Chemical Analysis (Chicago Area)

	Percent		*Percent*
Silica	40 to 50	Titanium	0 to 1
Alumina	15 to 24	Total Alkalies	3 to 6
Iron Oxides	12 to 19	Sulfuric Anhydride	1 to 4
Lime	4 to 8	Loss on Ignition	0.5 to 5
Magnesia	0.5 to 2	Carbon	0.5 to 3

Color—light gray to tan (much the same as portland cement)
Weight per cu ft—75 lb
Passing 325 mesh sieve—88 to 95 percent
Specific surface (Blaine)—2800 to 4500 sq cm per gram

Note: Chemical analysis varies widely with the parent material burned and condition under which it is burned, necessitating a close check on carbon content which has a direct bearing on the finished concrete product.

Pozzolanic Action of Fly Ash

The history of pozzolans is old in the art of masonry and concrete construction, dating back to the days of ancient Rome. The modern term "pozzolan" is in fact derived from the ancient term "pozzuolana" which referred to a volcanic ash found near Pozzuoli, Italy, which, when mixed with a quick lime, produced a hydraulic cement.

Most of the natural pozzolans in this country are found in the west and have been used there. Some outstanding examples are the use of a pumice in Friant Dam, a calcined opaline shale in Davis Dam, and a calcined diatomaceous earth in Bonneville Dam and in one of California Edison Company's dams on the St. Joaquin River.

Most fly ash is pozzolanic, high in silica, low in lime. When mixed with portland cement, it combines with excess lime liberated by the cement in hydration, forming addi-

tional insoluble "cementitious" compounds. In the middle west and east, if pozzolans are desired, artificial pozzolans, such as fly ash, are generally more economical.

Use of Fly Ash

Fly ash is used as a pozzolanic material and as an admixture in portland cement concrete.

The most notable instance of its use was in Hungry Horse Dam in Montana, which was completed in 1953. By using 90 lb of fly ash per cu yd of concrete, it was possible to use two and three sacks of cement per cu yd for interior and exterior, respectively. In comparison, four sacks of cement were used per cu yd of concrete during the construction of the Hoover Dam in which no fly ash was employed. However, there have been many other structures placed using fly ash: in 1938, the Chicago Sanitary District placed about ½ mile of paving around its North Side Disposal Plant; in 1936, a Chicago district electric corporation placed several thousand feet of retaining wall along Lake Michigan, using a blend consisting of 75 percent portland cement and 25 percent fly ash in a 1–2–4 mix; in 1947, the Wisconsin Highway Commission placed two test sections of pavement. In the Chicago area, fly ash has also been used in the construction of schools, city garages, office buildings, subways, concrete pipe, concrete blocks, and many precast concrete items.

The American Society for Testing Materials has prepared a Tentative Specification for Fly Ash for use as an Admixture in Portland Cement Concrete (C 350 54T) where the increased quantities of suitable fine materials may be indicated to promote workability and plasticity.

Producers Claims for Fly Ash and Observations

Producers claim that fly ash used in concrete structures improves placeability and finishing characteristics, reduces permeability, improves resistance to sulphate-bearing soils or water, lowers heat of hydration, reduces expansion caused by the cement-aggregate reaction and provides some saving in cost due to substituting fly ash for cement.

They also claim that when fly ash is used in concrete products, the result is better plasticity and cohesiveness, more uniform surface texture of units and sharper edges and corners, less sticking to molds and pallets and reduction of abrasion on wearing parts.

However, the following observations are pertinent in the use of fly ash: the improvement in placement, finishing and reduction in permeability are most noticeable in instances where the sand is deficient in fine material; the resistance to sulphate-bearing soils and water will not be improved as much as by the use of sulphate-resisting cement; heat of hydration is reduced because of the lower cement content; reduced expansion caused by cement-aggregate reaction is dependent upon the fly ash having pozzolanic properties; the added cost of handling and measurement of fly ash on an ordinary job may be greater than the saving made by the substitution of fly ash for cement. In concrete products the most advantage is gained when high-pressure steam curing is used.

Precautions

The fineness and carbon content of fly ash from plant to plant may vary greatly, and it has been found that very fine fly ash of low carbon content is superior when used as a pozzolan.

The carbon content of fly ash reduces both the strength of the concrete and the air content entrained in the concrete with a given quantity of air-entraining agent; hence the amount of air-entraining agent should be increased in fly-ash concrete in order

that the proper air content is maintained. The higher the carbon content, the greater the reduction of strength and air entrainment.

Lower strength at 7 to 28 days will result for concrete containing not more than 30 percent of fly ash, by weight, of the total cementitious materials; but, at one year of age, the strength of this concrete approximately equals the strength of concrete made from portland cement alone, providing favorable temperature and moisture conditions are maintained. More than 30 percent of fly ash will result in reduced strength of concrete at any age.

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7. "Effect of Substitutions of Fly Ash for Portions of Cement in Air-Entrained Concrete", Guy H. Larson, Highway Research Board Proceedings, Vol. 29, 1949; Vol. 32, 1953; and Vol. 33, 1954.

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9. "Pozzolanic Materials—With Special Reference to Their Use in Concrete Pipe", Raymond E. Davis, Technical Memorandum, American Concrete Pipe Association, Sept. 1, 1954.

10. "Verify Quality of Fly Ash Before Using", Harry F. Thomson, Concrete Manufacture Section of Pit and Quarry, Jan. 1956.

11. "Role of Fly Ash in Precast Products", Harry F. Thomson, Concrete Manufacture Section of Pit and Quarry, Feb. 1956.

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13. "Use of Fly Ash in Concrete", by Albert G. Timms and William E. Grieb, Highway Research Engineers, Public Roads, Vol. 29, No. 6, Feb. 1957.

14. "Investigations Relating to the Use of Fly Ash as a Pozzolanic Material and as an Admixture in Portland Cement Concrete", L. John Minnick, ASTM Proceedings, 1954.

15. "Tentative Specification for Fly Ash for Use as an Admixture in Portland Cement Concrete", ASTM Specifications C 350–54T.

Report of Committee 3—Ties

F. J. FUDGE, *Chairman,*

W. E. FUHR,
Vice Chairman,

R. S. BELCHER (E)
A. C. BLACK
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R. G. BROHAUGH
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G. B. CAMPBELL
C. J. CODE
E. L. COLLETTE
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F. F. HORNIG
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L. W. KISTLER
C. M. LONG
J. W. NEIKIRK
H. B. ORR
R. W. ORR
C. A. PEEBLES
R. R. POUX
R. B. RADKEY
W. C. REICHOW
N. B. ROBERTS
H. S. ROSS
N. A. SALZANO
C. V. SCHUTT
R. B. SMITH
E. F. SNYDER
L. S. STROHL
S. THORVALDSON
G. A. WILLIAMS

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Extent of adherence to specifications.
   No report.

3. Substitutes for wood ties.
   Progress in study, but no report.

4. Tie renewals and costs per mile of maintained track.
   The report on this assignment, consisting of the annual statistics compiled by the Bureau of Railway Economics, AAR, and providing information about tie renewals and cost data for 1957, was published in Bulletin 544, June–July 1958.

5. Methods of retarding the splitting and mechanical wear of ties including stabilization of wood, collaborating with Committee 5.
   Oral report to be made at annual meeting.

6. Bituminous coating of ties for protection from the elements.
   Progress in study, but no report.

8. End splitting of cross and switch ties.
   Oral report to be made at annual meeting.

9. Means for effecting greater utilization of timberland growth available for cross tie production.
Final report, presented as information ..... page 498

THE COMMITTEE ON TIES,
F. J. FUDGE, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 9

Means for Effecting Greater Utilization of Timberland Growth Available for Cross Tie Production

W. R. Jacobson (chairman, subcommittee), P. D. Brentlinger, C. S. Burt, L. P. Drew, F. J. Fudge, M. J. Hubbard, L. W. Kistler, R. B. Smith, L. S. Strohl.

Your committee submits the following final report as information only.

Under its Specifications for Cross Ties, the American Railway Engineering Association recognizes a broad generic classification of woods suitable for cross ties. The latest edition of the United States Department of Agriculture Check List of Trees in the United States lists 162 species as commercially important; the AREA lists 135 of the 162 species as acceptable for cross ties. The statistics issued by the Division of Forest Economics Research, Forest Service, United States Department of Agriculture, in cooperation with the American Wood Preserver's Association show, for the past five years, the following figures: of the total number of ties treated, approximately 50 percent were oak and 33 percent were mixed hardwoods and gum. The latter are classed together because it has been found on field inspection visits by the committee that most gum inventories include some mixed hardwoods and, in other than northern stocks, most mixed hardwoods include some gum. Thus, it can be seen that there is now being used a considerable amount of the mixed hardwood species.

Listed below are the statistics for the past five years, referred to above.

	1953		*1954*		*1955*	
	Percent	*No Ties*	*Percent*	*No Ties*	*Percent*	*No. Ties*
Oak	48	18,698,942	50	16,646,709	55	14,431,610
Gum	10	3,734,095	10	3,180,068	8	1,947,411
Mixed hardwood	22	8,526,410	23	7,480,991	19	5,071,353

	1956		*1957*	
	Percent	*No Ties*	*Percent*	*No Ties*
Oak	46	11,960,262	51	15,551,624
Gum	10	2,660,014	13	3,909,563
Mixed hardwoods	23	5,988,063	20	6,199,638

Note: Balance of percentage not shown are softwood ties.

In any discussion of mixed hardwoods, it must be borne in mind that there is a wide difference in performance by species in this category, which includes, for example, hickory, with a specific gravity of 0.65, and yellow poplar, with a specific gravity of 0.40. The mixed hardwoods, generally classified in Group Td, are extremely heterogeneous, having a wide variation in those characteristics necessary for good tie timber.

Many objections to various species in this category have been raised, with considerable merit. Probably the greatest problem, generally, is seasoning characteristics. Many of these species, while having all the most desirable characteristics for ties, are prone to serious checking during the seasoning process. High on this list are the hickories, white

ash, beech and elm. Recent research is beginning to show how this problem can be controlled; e.g., by dowelling, vapor drying and controlled seasoning.

Further accentuating this problem are the growth characteristics of mixed stands, and logging habits that preclude the separate stacking by species. Several of these species can be and are logged and stacked separately. In this classification are hard maple, yellow birch, beech and hickory. In some local areas, possibly elm, sycamore and cottonwood could also be separated. Correlated with the problem, of course, is the marketing of great quantities of lumber of these mixed hardwood species.

Modern wood preserving methods, along with incising of some of these species, have just about eliminated this particular objection to the use of mixed hardwoods.

Over the years, many test tracks have been established, and the test results have been published in past Proceedings of this Association. These should be reviewed and the results evaluated in relation to any particular railroad. In a paper presented to the Railway Tie Association and published in the November 1953 issue of the Cross Tie Bulletin, C. B. Harveson, then chief engineer maintenance, Baltimore and Ohio Railroad, said:

"In conclusion we can say with a considerable feeling of certainty, that the mixed hardwood species are a very valuable adjunct to our cross tie resources. We know we have obtained very good results from them in tie life and we expect even better in the future, although at some added cost. But it should be considered that the purchase and use of these ties enable us to take advantage to the fullest extent of our available forest growth with a consequent reduction in over-all cost of production, and, this being the case, we are well satisfied with our experience with the mixed hardwood cross ties."

Further, the results of testing on various railroads have shown that maple, beech, birch, cherry, gum and hickory have compared very favorably with the species of oak tested. In fact, superior results were obtained with maple.

Again, it must be pointed out that there are many other species in the Td grouping that have not given as good results as indicated above. In this category are such species as black ash, cottonwood, aspen, etc.

Summary

As the result of careful consideration of all of the factors involved in this study, the committee feels that Art. 1. Kinds of Wood, Sec. A, of the Specifications for Cross Ties, should remain unchanged.

Furthermore, the committee proposes to give consideration to making the following revisions in the Specifications for Cross Ties:

a. Under Sec. F. DELIVERY, Art. 3. Grouping, add the following: "Ties shall be separated by species, or groups of species, in accordance with the purchase order, or with the specifications of the individual railroad purchasing the ties."

b. Under Sec. F. DELIVERY, Art. 4. Class U—Ties Which May Be Used Untreated, eliminate the groupings, Ua, Ub, etc. List the species alphabetically by hardwoods and softwoods instead.

c. Under Sec. F. DELIVERY, Art. 5. Class T—Ties Which Should Be Treated, eliminate the groupings Ta, Tb, etc. List the species alphabetically by hardwoods and softwoods instead, or list the species by hardwoods and softwoods, based on composite strength and with direct reference to the Wood Handbook, published by the United States Department of Agriculture.

The committee also recommends the following:

1. All railroads should have a complete knowledge of species native to their right-of-way and their procurement territory.
2. The technical and economical aspects of each species should be determined.
3. Use to the fullest extent possible all species to assist in proper balance of growing stocks in the forests.
4. Investigate the newest methods for seasoning and treating.
5. That Committee 17—Wood Preservation, accept an assignment on separation of species for seasoning and treatment.

Report of Committee 28—Clearances

S. M. DAHL, *Chairman,*
J. G. GREENLEE,
Vice Chairman,

C. O. BIRD
E. S. BIRKENWALD
B. BRISTOW
D. H. BROWN
W. T. DAVIS
J. E. FANNING
J. E. GOOD
A. R. HARRIS
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C. F. INTLEKOFER
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J. W. WALLENIUS
A. M. WESTON
H. G. WHITTET, JR.
R. L. WILLIAMS
M. A. WOHLSCHLAEGER
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No Report.

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, and with Mechanical and Operating-Transportation Divisions, AAR.

   Progress report, including recommended third-rail clearance diagrams, presented as information ..... page 502

3. Review clearance diagrams for recommended practice, collaborating with AREA committees concerned and the AAR Joint Committee on Clearances.

   Progress in study, but no report.

4. Compilation of the railroad clearance requirements of the various states.

   Progress report bringing up to date the tabulation of the clearance requirements of the various states ..... page 502

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating with the Mechanical Division, AAR.

   Progress report, including recommended method of determining clearance allowances for horizontal movement of passenger cars, presented as information ..... page 503

7. Methods of measuring high and wide shipments.

   Progress report, presented as information ..... page 503

THE COMMITTEE ON CLEARANCES,
S. M. DAHL, *Chairman.*

AREA Bulletin 547, December 1958.

Report on Assignment 2

Clearances as Affected by Girders Projecting Above Top of Track Rails, Structures, Third-Rail, Signal and Train Control Equipment

Collaborating with Signal and Electrical Sections, and with Mechanical and Operating-Transportation Divisions, AAR

J. G. Greenlee (chairman, subcommittee), C. O. Bird, E. S. Birkenwald, D. H. Brown, S. M. Dahl, W. T. Davis, J. E. Good, A. G. Neighbour, W. S. Ray, A. M. Weston, H. G. Whittet, Jr., R. L. Williams.

In the following report of progress in gathering information pertaining to clearance in third-rail territory, your committee submits two diagrams—No. 1 for tangent track and curves up to 7 deg 10 min (800 ft radius), and No. 2 for curves exceeding 7 deg 10 min.

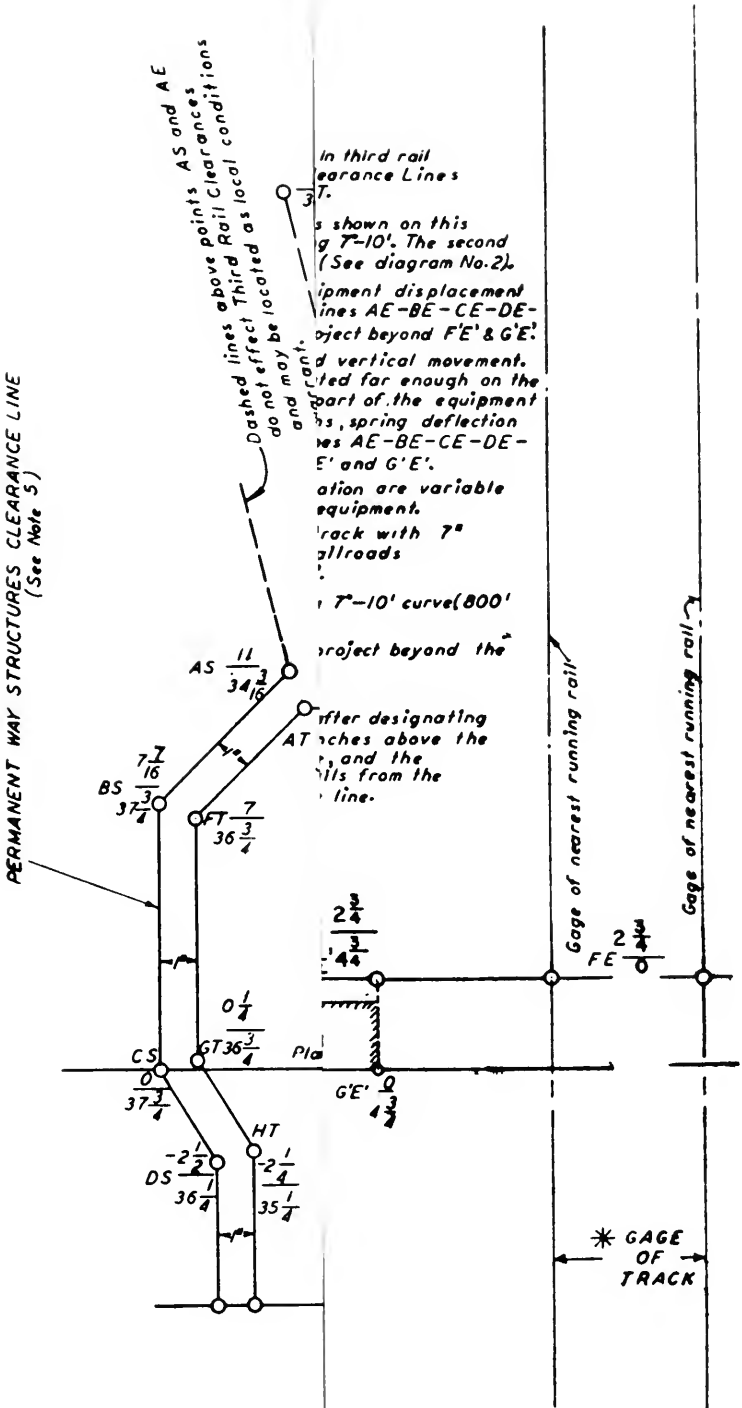
These diagrams were submitted to the Signal and Electrical Sections, and Mechanical and Operating-Transportation Divisions, AAR, which, after considerable deliberation, decided that they were generally acceptable. However, the Electrical Section subsequently recommended that the two diagrams be combined into one, which will be done later.

Report on Assignment 4

Compilation of the Railroad Clearance Requirements of the Various States

J. F. Smith (chairman, subcommittee), S. M. Dahl, J. G. Greenlee, C. F. Intlekofer, W. P. Kobat, A. G. Neighbour, R. C. Nissen, A. D. Quackenbush, H. G. Whittet, Jr., M. A. Wohlschlaeger.

Your committee submits as information a tabulation of the clearance requirements of the various states brought up to date as of November 17, 1958. In it, attention is called to the fact that, as the result of recent orders, the clearance requirements of the states of Connecticut, Kansas, Maine, Montana, New Hampshire, Oklahoma and Rhode Island are shown for the first time; also that revisions in clearance requirements are shown for the states of Massachusetts, Pennsylvania, South Dakota and Washington.


PERMANENT WAY STRUCTURES CLEARANCE LINE
(See Note 5)
Dashed lines above points AS and AE do not effect Third Rail Clearances and may be located as local conditions
In third rail
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(See diagram No.2).
ipment displacement
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part of the equipment
s, spring deflection
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equipment.
rack with 7"
allroads
7°-10' curve(800'
project beyond the
AS 11/34 3/16
after designating
AT
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, and the
ils from the
line.
BS 7 7/16 / 37 3/4
FT 7 / 36 3/4
CS 0 / 37 3/4
GT 0 1/4 / 36 3/4
HT
DS -2 1/2 / 36 1/4
-2 1/4 / 35 1/4
G'E' 0 / 4 3/4
FE 2 3/4 / 0
Gage of nearest running rail
Gage of nearest running rail
* GAGE OF TRACK

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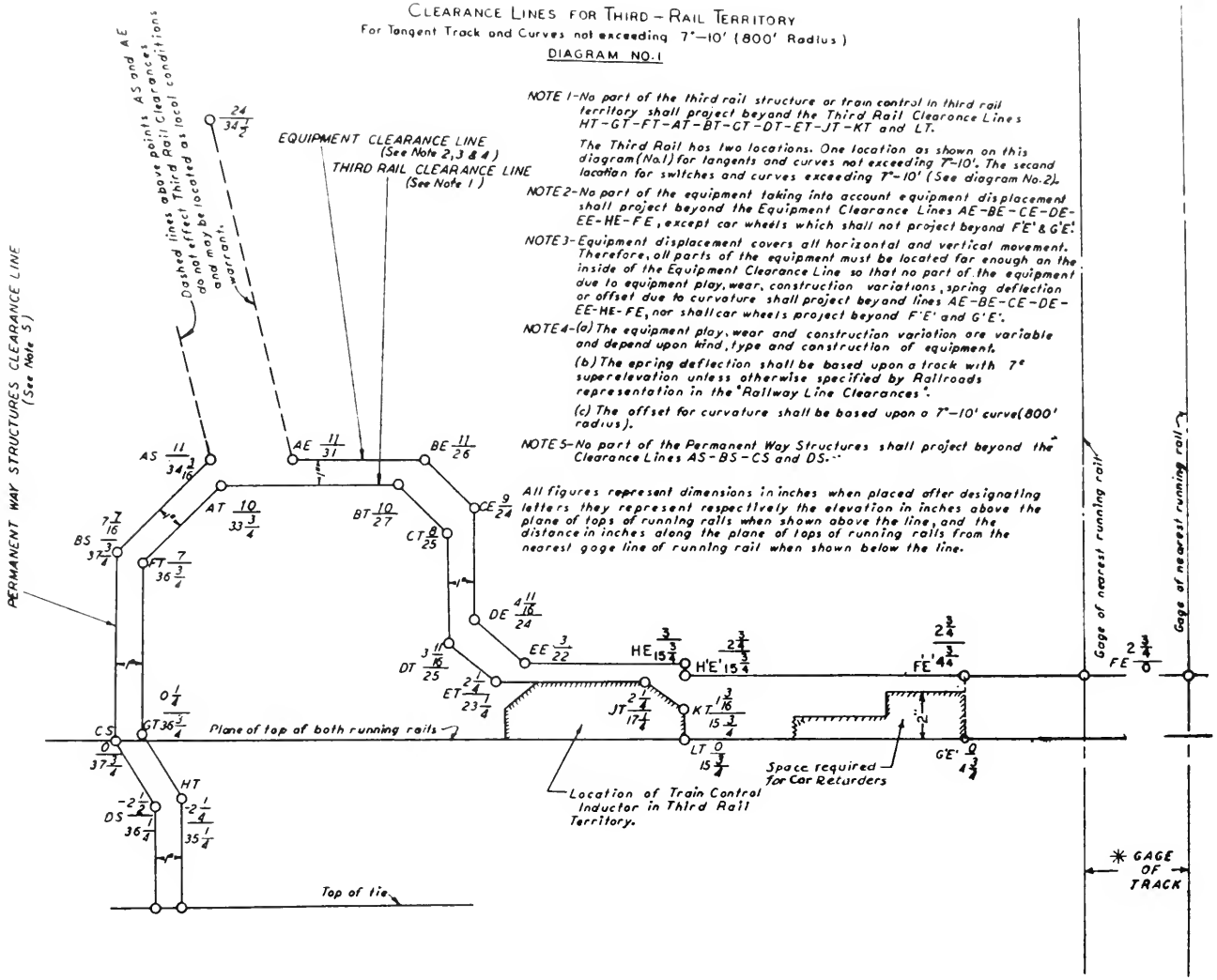
CLEARANCE LINES FOR THIRD – RAIL TERRITORY

For Tangent Track and Curves not exceeding 7°–10' (800' Radius)

DIAGRAM NO. 1



NOTE 1–No part of the third rail structure or train control in third rail territory shall project beyond the Third Rail Clearance Lines HT–GT–FT–AT–BT–CT–DT–ET–JT–KT and LT.

The Third Rail has two locations. One location as shown on this diagram (No. 1) for tangents and curves not exceeding 7°–10'. The second location for switches and curves exceeding 7°–10' (See diagram No. 2).

NOTE 2–No part of the equipment taking into account equipment displacement shall project beyond the Equipment Clearance Lines AE–BE–CE–DE–EE–HE–FE, except car wheels which shall not project beyond F'E' & G'E'.

NOTE 3–Equipment displacement covers all horizontal and vertical movement. Therefore, all parts of the equipment must be located far enough on the inside of the Equipment Clearance Line so that no part of the equipment due to equipment play, wear, construction variations, spring deflection or offset due to curvature shall project beyond lines AE–BE–CE–DE–EE–HE–FE, nor shall car wheels project beyond F'E' and G'E'.

NOTE 4–(a) The equipment play, wear and construction variation are variable and depend upon kind, type and construction of equipment.

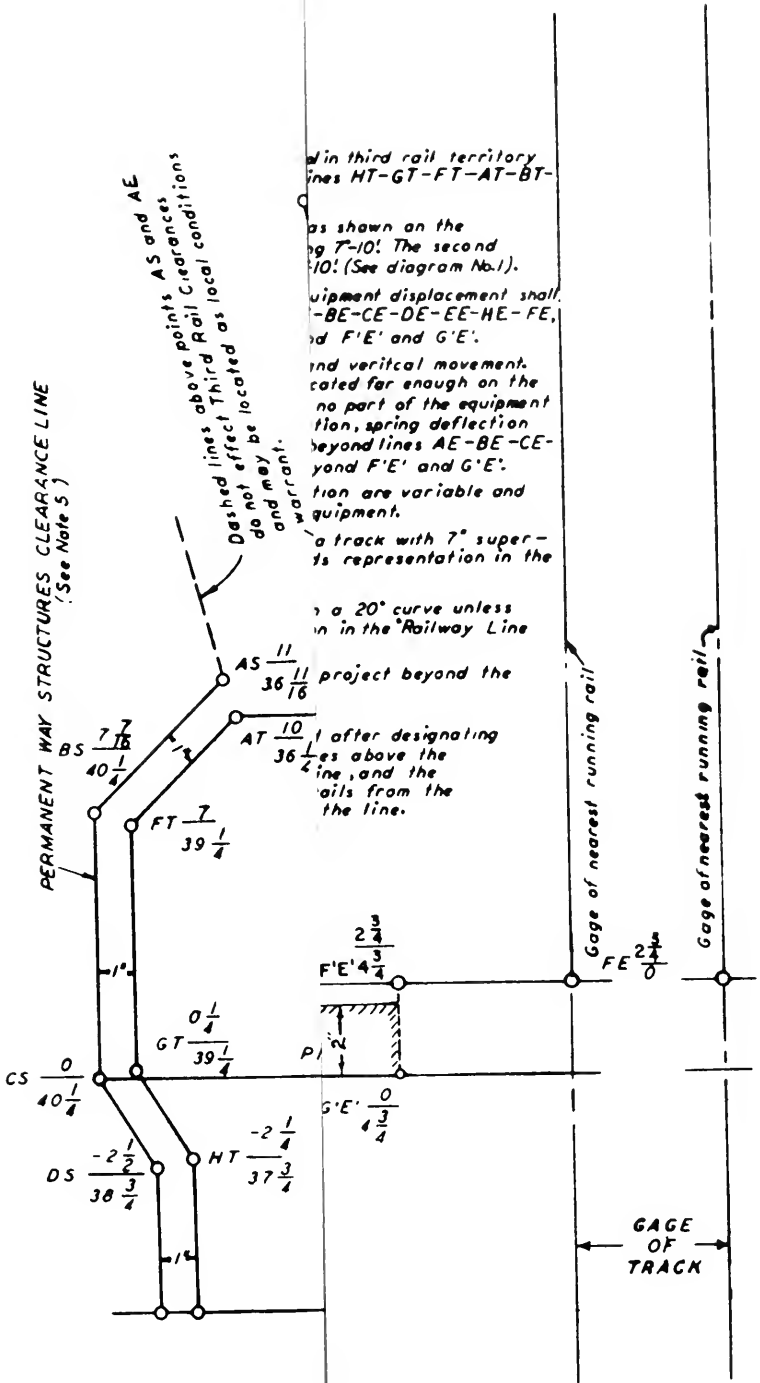
(b) The spring deflection shall be based upon a track with 7" superelevation unless otherwise specified by Railroads representation in the "Railway Line Clearances".

(c) The offset for curvature shall be based upon a 7°–10' curve (800' radius).

NOTE 5–No part of the Permanent Way Structures shall project beyond the Clearance Lines AS–BS–CS and DS.

All figures represent dimensions in inches when placed after designating letters they represent respectively the elevation in inches above the plane of tops of running rails when shown above the line, and the distance in inches along the plane of tops of running rails from the nearest gage line of running rail when shown below the line.

8-18-881

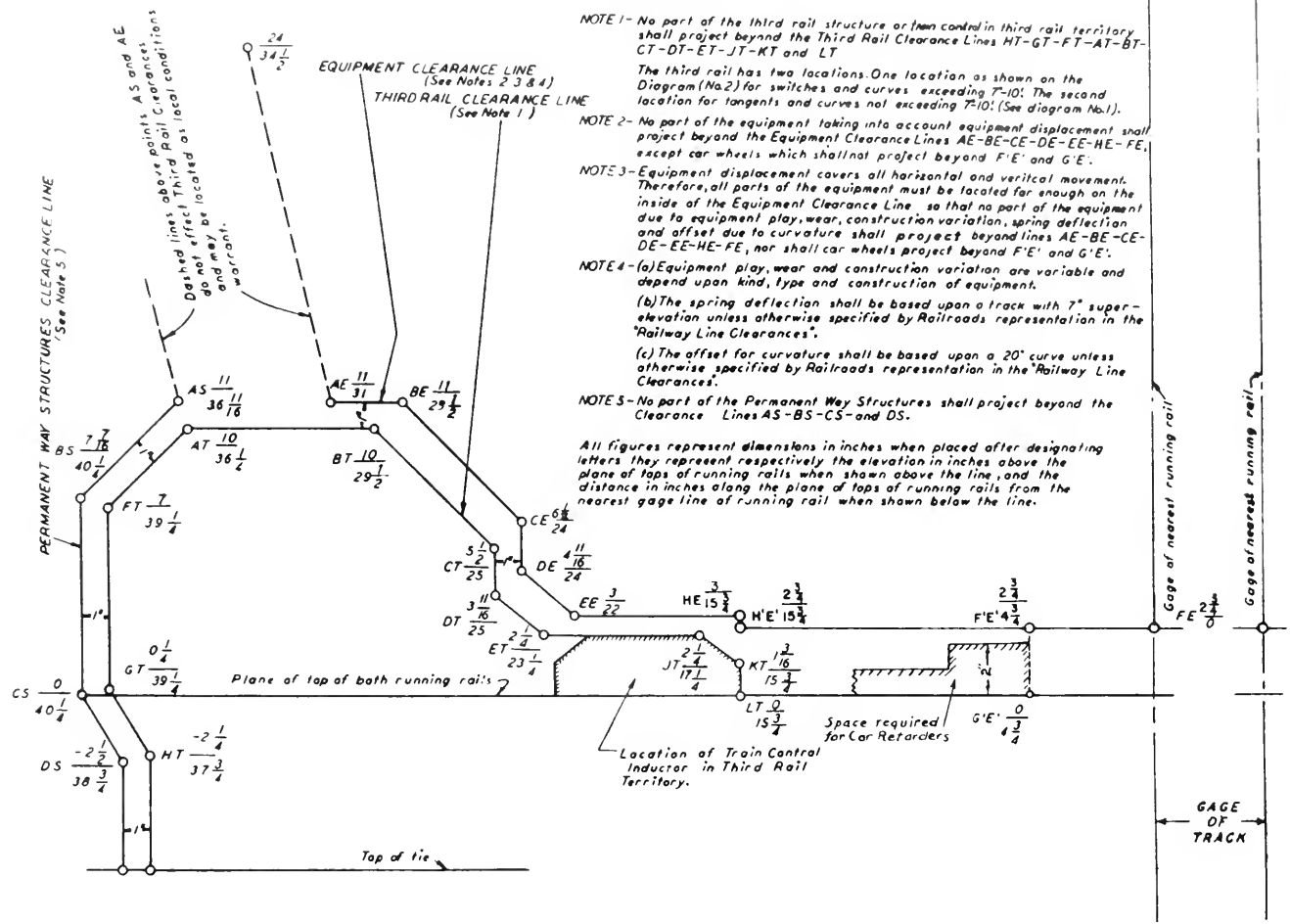

PERMANENT WAY STRUCTURES CLEARANCE LINE (See Note 5)
Dashed lines above points AS and AE effect Third Rail Clearances do not may be located as local conditions and warrant.
AS 11 / 36 11/16
AT 10 / 36 1/4
BS 7 7/16 / 40 1/4
FT 7 / 39 1/4
GT 0 1/4 / 39 1/4
CS 0 / 40 1/4
DS -2 1/2 / 38 3/4
HT -2 1/4 / 37 3/4
F'E' 4 3/4 2 3/4
FE 2 3/4 / 0
G'E' 0 / 4 3/4
1"
1"
Gage of nearest running rail
Gage of nearest running rail
GAGE OF TRACK

8-15-58

CLEARANCE LINES FOR THIRD – RAIL TERRITORY

For Switches and Curves exceeding 7° – 10' (800' Radius)

DIAGRAM NO. 2



NOTE 1 – No part of the third rail structure or item control in third rail territory shall project beyond the Third Rail Clearance Lines HT-GT-FT-AT-BT-CT-DT-ET-JT-KT and LT

The third rail has two locations. One location as shown on the Diagram (No. 2) for switches and curves exceeding 7°-10'. The second location for tangents and curves not exceeding 7°-10'. (See diagram No. 1).

NOTE 2 – No part of the equipment taking into account equipment displacement shall project beyond the Equipment Clearance Lines AE-BE-CE-DE-EE-HE-FE, except car wheels which shall not project beyond F'E' and G'E'.

NOTE 3 – Equipment displacement covers all horizontal and veritcal movement. Therefore, all parts of the equipment must be located far enough on the inside of the Equipment Clearance Line so that no part of the equipment due to equipment play, wear, construction variation, spring deflection and offset due to curvature shall project beyond lines AE-BE-CE-DE-EE-HE-FE, nor shall car wheels project beyond F'E' and G'E'.

NOTE 4 – (a) Equipment play, wear and construction variation are variable and depend upon kind, type and construction of equipment.

(b) The spring deflection shall be based upon a track with 7" super-elevation unless otherwise specified by Railroads representation in the "Railway Line Clearances".

(c) The offset for curvature shall be based upon a 20° curve unless otherwise specified by Railroads representation in the "Railway Line Clearances".

NOTE 5 – No part of the Permanent Way Structures shall project beyond the Clearance Lines AS-BS-CS-and DS.

All figures represent dimensions in inches when placed after designating letters they represent respectively the elevation in inches above the plane of tops of running rails when shown above the line, and the distance in inches along the plane of tops of running rails from the nearest gage line of running rail when shown below the line.

8-15-58

SIDE CLEARANCES

PLATFORMS						SIGNALS					BRIDGES		TUNNELS		ENGINE HOUSES ENTRANCE ENCLOSED BLDGS	ICING DOCKS	MAIL CRANES	WATER COLUMNS	WATER TANKS	STOCK CHUTES, ORE CHUTES, ETC
FREIGHT						SWITCH BOXES, MECHANISM ETC.		LOW BETWEEN TRACKS		HIGH	GENERAL	LESSER CLEARANCES PERMITTED IN QUADRANTS	GENERAL	LESSER CLEARANCES PERMITTED IN QUADRANTS						
HEIGHT	CLEARANCE	HEIGHT	CLEARANCE	HEIGHT	CLEARANCE	HEIGHT	CLEARANCE	HEIGHT	CLEARANCE											
		4'-0"	7'-3"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-8"	7'-8"	EXEMPT	8'-0"	8'-6"	LESS THAN 8'-8"
OVER 4'-0"	8'-0" 8'-6"	4'-0"	5'-9"[6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"[19]	6'-8"	8'-6"	8'-0"		
		4'-0"	7'-6"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes[1]	8'-0"	Yes		7'-8"		8'-0"	8'-6"	LESS THAN 8'-8"
OVER 4'-0"	8'-0" 8'-8"	4'-0"	5'-9"[6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"		
		4'-0"	LESS THAN 8'-6"[6]	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0"[19]	8'-6"	6'-5"	8'-0"	8'-6"	8'-0"
		4'-0"	LESS THAN 8'-6"[6]	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0"[19]	7'-8"	6'-5"	8'-0"	8'-6"	8'-0"
		4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"						6'-0"	7'-8"				
4'-0"	7'-3"	OVER 4'-0"	8'-6"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	Yes	EXEMPT	6'-8"	8'-6"	8'-0"		5'-9"
			5'-8"[9]					2'-8"	None	8'-0" 8'-6"	8'-0"	Yes			7'-0"[19]			7'-6" 8'-0"	9'-0"	
											8'-0"		8'-0"							
			5'-9"[6]					2'-8"	None	8'-0"	8'-0"	Yes			7'-0"[19]		6'-3"	7'-6" 8'-0"	9'-0"	7'-0"
OVER 4'-0"	6'-0" 6'-6"	4'-0"	5'-9"[6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"[19]	6'-8"	8'-6"	8'-0"	8'-0"	8'-0"
4'-0" TO 9'-0"	6'-0"	4'-0"	5'-9"[6]	4'-6"	8'-0"[3]	4"	3'-0"	3'-2" 4'-0"	5'-8" 7'-0"	8'-0"	8'-0"	Yes	8'-0"	No	7'-0"[19]	6'-0"	6'-1"	8'-0"	8'-0"	8'-0"
4'-6"	8'-0"	4'-0"	5'-7"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"		8'-0"					7'-8"		8'-0"	—	8'-0"
			5'-9"[6]					3'-0"	6'-6"	8'-6"	8'-6"	No	8'-6"	No		8'-6"	8'-6"	8'-6"	8'-6"	8'-6"
			8'-6"[15]			← E	X	E	M	P	T →		8'-6"[15]				EXEMPT	EXEMPT	EXEMPT	EXEMPT
			8'-6"								8'-6"	Yes	8'-6"	Yes	NOTE 14		8'-6"	8'-6"	8'-6"	8'-6"
		CAR FLOOR	5'-9"[6]			3"	4'-2"	0 to 4	5 to 8	8'-6"	8'-0"	Yes	8'-6"	Yes	6'-0"	8'-6"	6'-5"	8'-6"	8'-6"	8'-6"
OVER 4'-0"	8'-6"	4'-0"	5'-9" OR 7'-3"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	Yes	EXEMPT	5'-9"	8'-6"	8'-0"	8'-6"	6'-9"
OVER 4'-0"	8'-0" 8'-6"	4'-0"	5'-9"[6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"[19]	6'-8"	8'-6"	8'-0"		
		4'-0"	7'-3"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-8"	7'-8"	EXEMPT	8'-0"	8'-6"	LESS THAN 8'-6"
4'-0" TO 9'-0"	6'-0"	4'-0"	5'-9"[6]	4'-6"	8'-0"[3]	4"	3'-0"	3'-2" 4'-0"	5'-8" 7'-0"	8'-6"	8'-0"	Yes	8'-6"	No	7'-0"[19]	6'-0"	6'-1"	8'-6"	8'-6"	8'-6"
OVER 4'-0"	8'-0" 8'-6"	4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"		8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"		
		4'-0"	LESS THAN 8'-0"							8'-0"	8'-0"	No	8'-0"	No	8'-0"	8'-0"	8'-0"	8'-0"	8'-0"	8'-0"
			8'-0"							8'-0"	8'-0"	No	8'-0"	No				8'-0"	8'-0"	
OVER 4'-0"	8'-0" 8'-8"	4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"[19]	6'-8"	8'-6"	8'-0"		
4'-0"	7'-3"	OVER 4'-0"	8'-6"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	EXEMPT	7'-8"	8'-6"	8'-0"		
NOTE 20	NOTE 20	NOTE 20	NOTE 20	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"		8'-0"	Yes	8'-0"	Yes	8'-0"[19]	8'-0"		8'-0"		8'-0"
		4'-0"	LESS THAN 8'-6"[6]	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0"[19]	8'-6"	6'-5"	8'-0"	8'-6"	8'-0"
											8'-0"	No								
		CAR FLOOR	5'-9"[6]			4"	3'-0"			8'-0"	8'-0"	Yes			7'-0"	8'-6"	8'-6"	8'-0"	8'-6"	8'-6"
8"	4'-8"	NOTE 18	NOTE 18	4'-8"	8'-0"	4"	3'-0"		6'-6"	8'-0"	8'-0"	Yes	8'-0"	Yes	8'-0"	7'-0"	8'-5"	8'-0"	8'-0"	8'-0"
			8'-6"			8"	4'-0"	2'-6"	5'-6"	8'-6"	7'-6"	Yes			EXEMPT	7'-0"	EXEMPT	7'-0"		
1'-9"	5'-8"	4'-0"	7'-3"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-6"	7'-8"	EXEMPT	8'-0"	8'-6"	6'-6" 7'-6"
											7'-6"									
OVER 4'-0"	8'-6"	4'-0"	5'-9"	4'-6"	8'-0"[3]	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes[1]	8'-0"	No	7'-6"	5'-9"	8'-6"	8'-0"	8'-6"	8'-6"
		5'-0"	6'-4"[6]	OVER 5'-0"	8'-6"						8'-6"	No	8'-6"	No				8'-6"		
OVER 4'-0"	8'-0" 8'-6"	4'-0"	5'-9"[6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"[19]	6'-8"	8'-6"	8'-0"		
8"	4'-8"	4'-0"	5'-7"			4"	3'-0"	3'-0"	6'-0"		8'-0"	Yes	8'-0"	Yes				8'-0"		
		4'-0"	LESS THAN 6'-4"[6]								8'-0"	Yes	8'-0"	Yes				LESS THAN 6'-0"		

GENERAL NOTES

OVERHEAD CLEARANCES CONVERTED TO TOP OF RAIL IF LAWS PROVIDE BASE OF RAIL USING 6" DIFFERENCE

CLEARANCES GENERALLY FOR TANGENT TRACK. MOST LAWS SPECIFY INCREASES FOR CURVED OR SUPERELEVATED TRACK

SIDE CLEARANCES ARE FROM CENTER LINE OF TRACK.

[9] ENGINE HOUSES EXEMPT OR PERMITTED LESSER DIMENSIONS

[19] CHECK WITH RAILROAD INVOLVED FOR LATEST LOCAL AND STATE REGULATIONS

REVISED 12-1-56
REVISED: 12-2-55
REVISED: 11-54
REVISED: 12-17-51
REVISED 11-17-58
REVISED 12-1-57

LEGAL REQUIREMENTS—CLEARANCES

REGULATION REFERENCE	MILES OF TRACK AS OF DECEMBER 31, 1942		PERCENT OF TOTAL MILEAGE IN U.S.	CLEARANCES BASED ON MAXIMUM CAR SIZES		SPACING BETWEEN TRACKS: MAIN FREIGHT TRACKS	MAIN PASSENGER TRACKS	ADJACENT SUBSIDIARY TRACKS TO ANY MAIN TRACK	ANY TWO SUBSIDIARY FREIGHT TRACKS	ANY TWO SUBSIDIARY PASSENGER TRACKS	LADDER TRACK ADJACENT TO MAIN TRACKS, MECH OPERATED SWITCHES	LADDER TRACK ADJACENT TO MAIN TRACKS, HAND OPERATED SWITCHES	TWO ADJACENT PARALLEL LADDER TRACKS, MECH OPERATED SWITCHES	TWO ADJACENT PARALLEL LADDER TRACKS, HAND OPERATED SWITCHES	LEAD TRACKS IN YARDS AND CABOOSE TRACKS	REPAIR TRACKS	TEAM TRACKS IN PAIR	UNLOADING TRACKS AT PLATFORMS	OVERHEAD CLEARANCES: BRIDGES: GENERAL	BRIDGES: LESSER CLEARANCES PERMITTED IN QUADRANTS	TUNNELS: GENERAL	TUNNELS: LESSER CLEARANCES PERMITTED IN QUADRANTS	OVERHEAD STRUCTURES ETC: GENERAL	OVERHEAD STRUCTURES ETC: LESSER CLEARANCES PERMITTED IN QUADRANTS	ENGINE HOUSES ENTRANCE ENCLOSED BUILDINGS	BUILDINGS STRUCTURES ETC: GENERAL	BUILDINGS STRUCTURES ETC: LESSER CLEARANCES PERMITTED IN QUADRANTS	POLES	PLATFORMS: PASSENGER: HEIGHT	PASSENGER: CLEARANCE	FREIGHT: HEIGHT	FREIGHT: CLEARANCE	SIDE CLEARANCES: SIGNALS: HEIGHT	SIGNALS: CLEARANCE	SIGNALS: SWITCH BOXES, MECHANISM ETC	SIGNALS: LOW BETWEEN TRACKS	SIGNALS: HIGH	BRIDGES: GENERAL	BRIDGES: LESSER CLEARANCES PERMITTED IN QUADRANTS	TUNNELS: GENERAL	TUNNELS: LESSER CLEARANCES PERMITTED IN QUADRANTS	ENGINE HOUSES ENTRANCE ENCLOSED BLOCKS	ICING DOCKS	MAIL CRANES	WATER COLUMNS	WATER TANKS	STOCK CHUTES, ORE CHUTES, ETC
				WIDTH	HEIGHT																																											
ALABAMA	Notes 5 & 20		4906	214																																											
ARIZONA	DECISION No. 4252	1946	2215	0.97	10'-8"	15'-1"	14'-0"		15'0"	14'-0"		20'-0"	20'-0"	20'-0"	20'-0"			11'-6"	13'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	4'-8"		4'-0"	7'-3"	4'-6"	8'-0"	4"	3'-0"	3'-0"	8'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-8"	7'-8"	EXEMPT	8'-0"	8'-6"	16'-8"	
ARKANSAS	Case R-1012	1956	4383	1.91			14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"			13'-0"		22'-0"	Yes	23'-0"	Yes	22'-0"	Yes	17'-0"	8'-6"	Yes	8'-6"	8'	5'-0"	OVER 4'-0"	8'-0" OVER 4'-0"	4'-0"	5'-9"	4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"			
CALIFORNIA	Gen. Order 26-D	1948	7524	3.28	10'-10"	15'-6"	14'-0"	14'-0"	15'0"	14'-0"	14'-0"	20'-0"	20'-0"	20'-0"	20'-0"			13'-0"	13'-0"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	4'-8"		4'-0"	7'-6"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-8"			8'-0"	8'-6"		
COLORADO	DECISION No. 38476	1952	4450	1.94			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-0"	Yes	23'-0"	Yes	22'-6"	Yes	17'-0"	8'-6"	Yes	8'-6"	8'	5'-0"	OVER 4'-0"	8'-0" OVER 4'-0"	4'-0"	5'-9"	4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"			
CONNECTICUT	Docket 8995	1956	831	0.38			13'-0"	13'-0"	15'-0"	13'-0"	13'-0"	18'-0"	18'-0"	19'-0"	19'-0"	14'-0"		13'-0"	14'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	5'-2"		4'-0"	LESS THAN 7'-6"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0"	8'-6"	8'-6"	8'-0"			
DELAWARE	Order 214	1955	295	0.13			14'-0"	14'-0"	15'-0"	13'-6"	13'-6"	18'-0"	18'-0"	19'-0"	19'-0"	13'-6"	13'-6"	13'-0"	13'-6"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	8'-1" 4'-0"		4'-0"	LESS THAN 7'-6"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0"	8'-6"	8'-6"	8'-0"			
FLORIDA	Order 187	1953	5010	2.19			13'-6"	13'-6"			19'-0"	19'-0"						13'-0"		22'-0"						17'-0"	8'-0"		10'-0"	8'	4'-8"		4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"					6'-0"	7'-8"					
GEORGIA	Notes 5 & 20		8215	2.71																																											
IDAHO	Gen. Order 99	1955	2742	1.20	10'-10"	15'-8"	14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	20'-0"	20'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0" [19]	8'-6"	Yes	8'-6"	8'	4'-8"	4'-0"	7'-3"	OVER 4'-0"	8'-6"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	Yes	EXEMPT	6'-8"	8'-6"	8'-0"		5'-9"
ILLINOIS	Gen. Order 22	1920	11777	5.14			13'-6"	13'-0"	15'0"	13'-6"	13'-0"	15'-0"	17'-0"	17'-0"	19'-0"			LESS THAN 13'-6"	LESS THAN 13'-6"	21'-0" 21'-6"	Yes			21'-6"		BECOMES EFFECTIVE WHEN GOVERNS	8'-0"		9'-0"	8' 6"	5'-1"			5'-8"			2'-8"	None	8'-0"	8'-0"	Yes		7'-0"							
INDIANA	Statutes	1949	6857	2.99																22'-0"		22'-0"		22'-0"			8'-0"													8'-0"		8'-0"							
IOWA	Docket K-1281	1936	8906	3.89			14'-0"	13'-0"	15'-0"	13'-6"	13'-0"	15'-0"	17'-0"	17'-0"	19'-0"			LESS THAN 13'-6"	LESS THAN 13'-6"	22'-0"	Yes			22'-0"	No	HEIGHT OF CLEARANCE [18] GOVERNS	8'-0" [18]	No		8'	5'-0"			5'-9" [6]			2'-8"	None	8'-0"	8'-0"	Yes		7'-0" [9]		6'-3"	8'-0" [9]	9'-0"	7'-0"		
KANSAS	Docket 5884AR	1958	8479	3.70			14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"			13'-0"		22'-0"	Yes	23'-0"	Yes	22'-6"	Yes	18'-0" [19]	8'-6"	Yes	8'-6"	8'	5'-0"	OVER 4'-0"	8'-0" OVER 4'-0"	4'-0"	5'-9"	4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"	8'-0"	8'-0"	
KENTUCKY	Notes 5 & 20		3534	1.54																22'-0"		22'-0"		22'-0"																								
LOUISIANA	Notes 5 & 20		4292	1.87																																											
MAINE	Gen. Order 2	1956	1862	0.81																22'-0"	Yes	22'-0"	No	22'-0"	No	17'-0" [19]	8'-0"	No	8'-0"	12"	5'-4"	4'-6" OVER 8'-0"	4'-0"	5'-9"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	No	7'-0"	6'-0"	6'-1"	8'-0"	8'-0"	8'-0"	
MARYLAND	Order 5038	1953	1328	0.58			14'-0"		15'-0"	13'-6"		18'-0"	18'-0"	19'-0"				13'-0"		22'-0"		22'-0"		22'-0"	Yes	18'-0"	8'-6"	Yes		8"	5'-1"	4'-6"	8'-0"	4'-0"	5'-7"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"		8'-0"			7'-8"		8'-0"	—	8'-0"	
MASSACHUSETTS	Statutes	1956	1745	0.76			13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	17'-0"	17'-0"	17'-0"	17'-0"	13'-0"	13'-0"	13'-0"	13'-0"	22'-6"	No	22'-6"	No	22'-6"	No		8'-6"		8'-6"						5'-9" [6]			3'-0"	6'-0"	8'-6"	8'-6"	8'-6"	No	8'-6"	No		8'-6"	8'-6"	8'-6"	8'-6"	8'-6"	
MICHIGAN	Statutes	1957	7176	3.13			14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	EXEMPT	14'-0"	14'-0"	EXEMPT		22'-6"		22'-6" [7]		EXEMPT	8'-6" [15]		8'-6"						8'-6" [15]								8'-6" [15]		EXEMPT	EXEMPT	EXEMPT	EXEMPT	EXEMPT	
MINNESOTA	Statutes	1943 [8]	8371	3.65	10'-4"	14'-1½"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	17'-0"	17'-0"	19'-0"	19'-0"	14'-0"	14'-0"	14'-0"	14'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"	No	22'-0" [14]	8'-6"	No		9'-6" 4'-6"										8'-6"			8'-6"	Yes	NOTE 14		8'-6"	8'-6"	8'-6"	8'-6"	
MISSISSIPPI	Notes 5 & 20		3813	1.66																																										
MISSOURI	Gen. Order 24	1951	8939	3.03			13'-6"	13'-6"	13'-6"	13'-6"	13'-6"	17'-0"	17'-0"	19'-0"	19'-0"	13'-6"	13'-6"	13'-6"	13'-6"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes		8'-6"	Yes	8'-6"	4'-8" 5'-0"	4'-6" OVER 8'-0"		CAB FLOOR 8'-6"	4'-0"	5'-9" [6]			3"	4'-2"	0'-4"	5'-6"	8'-6"	8'-0"	Yes	8'-6"	Yes	8'-0"	8'-6"	6'-5"	6'-6"	8'-6"	8'-6"	
MONTANA	Order 2597	1956	5105	2.23	10'-10"	15'-6"	14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	20'-0"	20'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0" [19]	8'-6"	Yes	8'-6"	8"	4'-8"	OVER 8'-6"	4'-0"	5'-9" [6]	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	Yes	EXEMPT	5'-9"	8'-6"	8'-0"	8'-6"	6'-9"
NEBRASKA	Gen. Order 100	1956	5877	2.57			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	17'-0"	17'-0"	17'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	22'-0"	Yes	23'-0"	Yes	22'-6" [13]	Yes	17'-0" [19]	8'-8"	Yes	8'-6"	8"	5'-0"	OVER 8'-0"	8'-0" OVER 8'-0"	4'-0"	5'-9" [6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0" [9]	8'-0"	8'-6"	8'-0"		
NEVADA	Case 1158	1947	1828	0.60	10'-8"	15'-1"	14'-0"		15'0"	14'0"		20'-0"	20'-0"	20'-0"	20'-0"			11'-6"	13'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	4'-8"		4'-0"	7'-3"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-8"	7'-8"	EXEMPT	8'-0"	8'-6"	LESS THAN 8'-6"	
NEW HAMPSHIRE	Order 6922	1956	956	0.42			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	18'-0"	18'-0"	18'-0"	18'-0"	14'-0"	14'-0"	13'-0"	13'-0"	21'-0" [2]	Yes	21'-0" [2]	No	21'-0"	No	17'-0" [19]	8'-6"	No	8'-6"	12"	5'-4"	4'-0" OVER 8'-0"	4'-0"	5'-9" [6]	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-6"	No	7'-0"	6'-0"	6'-1"	8'-6"	8'-6"	8'-6"	
NEW JERSEY	Notes 5 & 20		2070	0.90																																										
NEW MEXICO	Order 2202	1953	2598	1.13			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"			13'-0"		22'-0"		23'-0"		22'-6"	Yes	17'-0" [19]	8'-6"	Yes	8'-6"	8"	4'-8"	OVER 8'-0"	4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"	8'-0"	Yes	8'-0"	Yes	7'-0"	8'-8"	8'-6"	8'-0"		
NEW YORK	Notes 5 & 20		7654	3.34																21'-6" [1]		21'-6" [1]		21'-6" [1]																								
NORTH CAROLINA	Notes 5 & 20		4628	2.02																																										
NORTH DAKOTA	Statutes	1913	5262	2.30	10'-6"	14'-2"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	13'-0"	21'-0"	No	21'-0"	No	21'-0"	No		8'-0"	No	8'-0"					4'-0"	EXEMPT 5'-9"					8'-0"	8'-0"	No	8'-0"	No	8'-0"	8'-0"	8'-0"	8'-0"	8'-0"	8'-0"	
OHIO	EXCEPT S. & S. DECIS.	1955	8435	3.68			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	15'-0"	15'-0"	16'-0"	16'-0"	14'-0"				21'-0"	No	21'-0"	No	21'-0"	No		8'-0"	No	8'-0"						8'-0"					8'-0"	8'-0"	No	8'-0"	No				8'-0"	8'-0"	
OKLAHOMA	Order 33347	1956	6018	2.63			14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-0"	Yes	23'-0"	Yes	22'-0"	Yes	17'-0" [19]	8'-6"	Yes	8'-6"	8"	5'-0"	OVER 8'-0"	8'-0" OVER 8'-0"	4'-0"	5'-9"			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0"	6'-8"	8'-6"	8'-0"		
OREGON	G. O. 33700	1955	3363	1.48	10'-10"	15'-6"	15'-0"	15'-0"	15'-0"	14'-0"	14'-0"	20'-0"	20'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0" [19]	8'-6"	Yes	8'-6"	8"	4'-8"	4'-0" OVER 8'-0"	7'-3"	OVER 8'-0"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	EXEMPT	7'-8"	8'-6"	8'-0"		
PENNSYLVANIA	Order	1954	10088	4.40			13'-6"	13'-6"	15'-0"	13'-6"		18'-0"	18'-0"	19'-0"				13'-6"		22'-0"	Yes	22'-0"	Yes	22'0"	Yes	18'-0" [11]	8'-6"	Yes	8'-6"	8"	5'-1"	NOTE 20	NOTE 20	4'-0"	5'-9"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"		8'-0"	Yes	8'-0"	8'-0"		8'-0"		8'-0"	
RHODE ISLAND	Docket 608	1955	189	0.08			13'-0"	13'-0"	15'-0"	13'-0"	13'-0"	18'-0"	18'-0"	19'-0"	19'-0"	14'-0"		13'-0"	14'-0"	18'-0"	Yes	18'-0"	Yes	18'-0"	Yes	18'-0" [19]	8'-6"	Yes	8'-6"	8"	5'-2"		4'-0"	LESS THAN 7'-6"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	8'-0" [9]	8'-6"	6'-5"	8'-0"	8'-6"	8'-0"	
SOUTH CAROLINA	Statutes	1942	3349	1.46																22'-0"	No																		8'-0"	No									
SOUTH DAKOTA	Order F2465	1957	3988	1.74																22'-6"	Yes			22'-6"	No	17'-0"	8'-6"	No	8'-6"	8'	4'-8"		CAB FLOOR 8'-6"	5'-9" [16]			4"	3'-0"		8'-0"	8'-0"	Yes			7'-0"	8'-6"	8'-6"	8'-0"	8'-6"	8'-6"	
TENNESSEE	Statutes	1949	3503	1.53			14'-0"	14'-0"	14'-0"	13'-0"	14'-0"	18'-0"	18'-0"	18'-0"	18'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	17'-0"	8'-0"	Yes	8'-0"	8'	4'-8"	8 4-8	NOTE 18	NOTE 18	4'-8"	8'-0"	4"	3'-0"		6'-6"	8'-0"	8'-0"	Yes	8'-0"	Yes	8'-0"	7'-0"	6'-5"	8'-0"	8'-0"	
TEXAS	Statutes	1925	5865	6.92																22'-0"	Yes	22'-0"		22'-0"		EXEMPT	8'-6"		8'-6"	12"	4'-8"			8'-6"				6'-4"	0'-2"	5'-6"	8'-6"	7'-6"	Yes			EXEMPT	7'-0"	EXEMPT	7'-0"		
UTAH	Gen. Order 66	1953	1908	0.83			14'-0"	14'-0"	15'-0" [2]	13'-0"	13'-0"	17'-0"	17'-0"	20'-0"	20'-0"			11'-6"	11'-6"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0"	8'-6"	Yes	8'-6"	8'	4'-8"	1'-9"	5'-8"	4'-0"	7'-3"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-6"	8'-0"	Yes	8'-0"	Yes	7'-6"	7'-8"	EXEMPT	8'-0"	8'-6"	8'-0"		
VERMONT	Statutes	1951	915	0.40																22'-0"		22'-0"		22'-0"			7'-6"													7'-6"									
VIRGINIA	Notes 5 & 20	1952	4205	1.84																																										
WASHINGTON	Gen. Order T&M	1950	5301	2.31	10'-10"	15'-6"	14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	20'-0"	20'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-6"	Yes	22'-6"	Yes	22'-6"	Yes	18'-0" [19]	8'-6"	No	8'-6"	8"	4'-8"	OVER 8'-6"	4'-0"	5'-9"	4'-6"	8'-0"	4"	3'-0"	3'-0"	6'-0"	8'-0"	8'-0"	Yes	8'-0"	No	7'-6"	5'-9"	8'-6"	8'-0"	8'-6"	8'-6"
WEST VIRGINIA	Gen. Order 121	1953	3763	1.64					15'-0"			15'-0"	15'-0"	18'-0"	18'-0"			13'-0"	13'-0"																													
WISCONSIN	Statutes	1951	6540	2.85			14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	22'-0"		22'-0"	No	22'-0"			8'-6"	No	8'-6"	8'	5'-1"			5'-0"	6'-4" [6]	OVER 8'-0"	8'-6"					8'-6"	No	8'-6"	No				8'-6"		
WYOMING	Docket 9287	1955	2008	0.86			14'-0"	14'-0"	15'-0"	14'-0"	14'-0"	17'-0"	17'-0"	20'-0"	20'-0"	14'-0"	14'-0"	13'-0"	13'-0"	22'-0"	Yes	23'-0"	Yes	22'-6" [4]	Yes	17'-0" [19]	8'-6"	Yes	8'-6"	8'	5'-3"	OVER 8'-0"	4'-0" OVER 8'-0"	4'-0"	5'-9" [6]			4"	3'-0"	3'-0"	6'-0"	8'-3"	8'-0"	Yes	8'-0"	Yes	7'-0" [9]	6'-8"	8'-6"	8'-0"		
DIST OF COLUMBIA	Order	1954					14'-0"	14'-0"	15'-0"	14'-0"	14'-0"		18'-0"		19'-0"			13'-0"		22'-0"	Yes	22'-0"	Yes	22'-0"	Yes	19'-0"	8'-6"			8'	4'-6"	4'-0"	5'-7"			4"	3'-0"	3'-0"	6'-0"		8'-0"	Yes	8'-0"							
CANADA	Gen. Order 345	1948					13'-0"	13'-0"	14'-0"	14'-0"	13'-0"	15'-0"	15'-0"	18'-0"	18'-0"			12'-0"	12'-0"	22'-0"	Yes	22'-0"	Yes	22'-0"			8'-6"	Yes						4'-0"	LESS THAN 8'-6"						8'-6"	Yes	8'-0"	Yes						

EXPLANATORY NOTES

1. EXCEPTIONS WHERE TRAINMEN OR YARDMEN ARE REQUIRED TO COUPLE OR UNCOUPLE CARS ON BRIDGE IN PERFORMING SWITCHING SERVICE ON A SWITCHING LEAD
2. BETWEEN MAIN AND FIRST TRACK OR SIDING AND FIRST TRACK IF SIDING LESS THAN 15'-0"
3. WHERE USED PRIMARILY IN LOADING OR UNLOADING REFRIGERATOR CARS
4. 18'-0" MAIN LINE TRACKS, 22'-0" ALL OTHERS
5. UNLESS OTHERWISE NOTED, REGULATIONS OF RAILROAD INVOLVED GOVERNS
6. IF NO CLEARANCE RESTRICTIONS ON OPPOSITE SIDE OF TRACK AND ON TRACKS OTHER THAN MAIN
7. TELL TALES TO BE ERECTED IF CLEARANCE LESS THAN 22'-0"
8. ALLOWS EXTENSION OF FACILITIES ON EXISTING CLEARANCES IF CONFORM TO 1913 LAWS
9. OVERHEAD CLEARANCES LESS THAN 21'-6" MUST BE LISTED WITH PUBLIC SERVICE COMMISSION
10. 7'-6" FOR SUBSIDIARY PASSENGER TRACKS
11. ON SIDE TRACKS FOR HANDLING PRODUCTS OF THE FOREST, MINES AND PITS
12. 22'-0" RECOMMENDED
13. 23'-6" FOR OVERHEAD HIGHWAY BRIDGES
14. ROUNDHOUSE AND SHOP DOOR ONLY 6'-6" HOR 17'-6" VERT. COMM ORDER NOV 11, 1944
15. 9'-0" ON CURVES LESS 400' RADIUS
16. EXCEPT IN CITIES WITH POWER TO REGULATE TRACK CENTER OF: 4'-1"-10" " " 4'-8"-14'-3" " " 8'-12"-14'-6" " " 12'-16"-14'-9" " " OVER 16'-15'-0"
17. 18" OR LESS: 4'-8" 8" TO 4'-0": 7'-6"
18. WAREHOUSE AND TRANSFER PLATFORMS, 5'-9" OVER 4'-0" FOR REEFERS: 8'-0"

GENERAL NOTES

OVERHEAD CLEARANCES CONVERTED TO TOP OF RAIL IF LAWS PROVIDE BASE OF RAIL USING 6" DIFFERENCE
CLEARANCES GENERALLY FOR TANGENT TRACK. MOST LAWS SPECIFY INCREASES FOR CURVED OR SUPERELEVATED TRACK
SIDE CLEARANCES ARE FROM CENTER LINE OF TRACK

19. ENGINE HOUSES EXEMPT OR PERMITTED LESSER DIMENSIONS
20. CHECK WITH RAILROAD INVOLVED FOR LATEST LOCAL AND STATE REGULATIONS

REVISED 12-1-56
REVISED 12-2-55
REVISED 11-1-54
REVISED 12-1-52
REVISED 11-17-58
REVISED 12-17-51

Report on Assignment 5

Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection

Collaborating with the Mechanical Division, AAR

E. E. Mills (chairman, subcommittee), C. O. Bird, D. H. Brown, S. M. Dahl, W. T. Davis, J. G. Greenlee, A. R. Harris, W. F. Hart, C. F. Intlekofer, C. E. Peterson, W. S. Ray, J. F. Smith, R. L. Williams, M. A. Wohlschlaeger.

Your committee presents, as information, a suggested method of determining clearance allowances for horizontal movements of passenger cars, with the view of presenting it for inclusion in the Manual after due collaboration with the Mechanical Division. (See chart on page 504).

The report is based on the results of field tests on passenger cars carried out by the AAR under the direction of G. M. Magee, director of engineering research. A report on these tests entitled "Passenger Ride Comfort on Curved Track" will be found in the Proceedings, Vol. 56, 1955, page 125. Other background material will be found in the reports of Committee 28 in the Proceedings, Vol. 56, 1955, page 559, and Vol. 59, 1958, page 661.

Report on Assignment 7

Methods of Measuring High and Wide Shipments

W. F. Hart (chairman, subcommittee), S. M. Dahl, J. G. Greenlee, C. O. Bird, D. H. Brown, W. P. Kobat, J. W. McMillen, E. E. Mills, C. E. Peterson, A. D. Quackenbush, J. F. Smith, J. W. Wallenius, H. G. Whittet, Jr.

Your committee submits the following report as information.

Data and requirements are being reviewed, looking to:

1. The economical design of a fixed measuring template to incorporate direct recording of clearances. Studies have been made of templates employing fixed columns, as well as of a movable template on fixed support.

2. The development of a uniform method of recording and transmitting initial measurements throughout the routing of a car.

3. The inclusion of approved methods of measurements in an appropriate manual.

Progress is being made, and the data developed will be submitted in later reports.

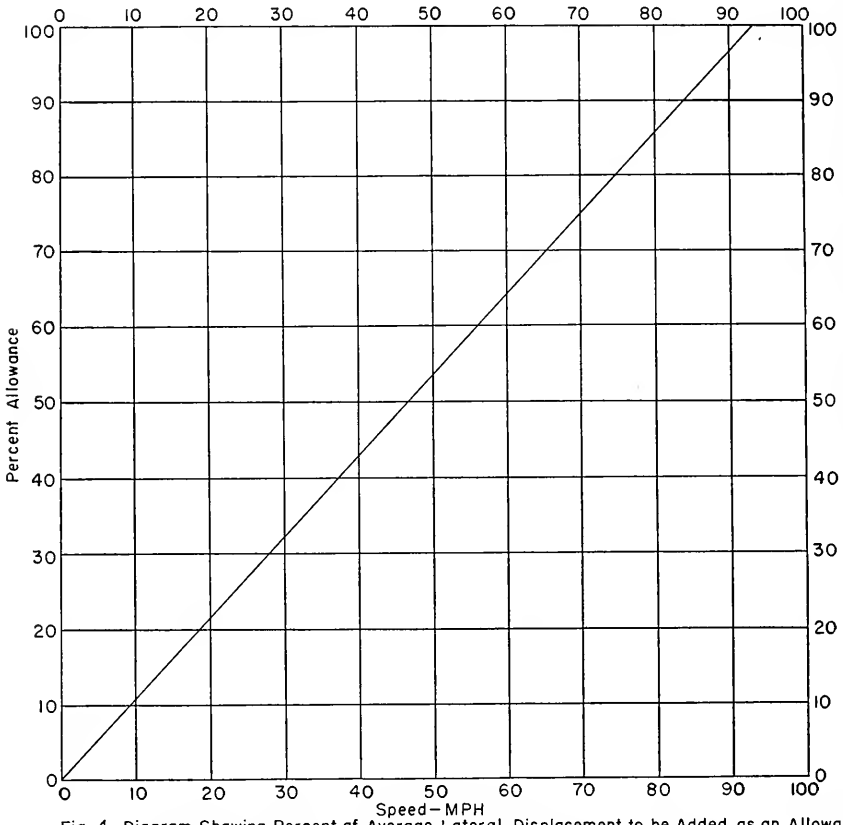


Fig. 4 - Diagram Showing Percent of Average Lateral Displacement to be Added, as an Allowance for the Effect of Track Irregularities and Dynamic Behavior of Passenger Cars.

Report of Committee 15—Iron and Steel Structures

D. V. MESSMAN, *Chairman*,
CORNELIUS NEUFELD,
Vice Chairman,
P. E. ADAMS
RAYMOND ARCHIBALD
R. C. BAKER
H. A. BALKE
ETHAN BALL
J. L. BECKEL
L. S. BEEDLE
J. E. BERNHARDT
E. S. BIRKENWALD
R. T. BLEWITT
M. BLOCK
H. F. BOBER
E. T. BOND, JR.
R. N. BRODIE
E. E. BURCH
ABRAM CLARK
J. G. CLARK
V. R. COOLEDGE
R. P. DAVIS
W. E. DOWLING
C. E. EKBERG
E. T. FRANZEN
T. L. FULLER
R. W. GUSTAFSON
C. D. HANOVER, JR.
A. R. HARRIS
J. M. HAYES
ALFRED HEDEFINE
D. L. JERMAN
E. A. JOHNSON
M. L. JOHNSON
B. G. JOHNSTON
J. C. KING
M. L. KOEHLER
SHU T'IEN LI
F. H. LOVELL
J. F. MARSH
F. M. MASTERS
M. L. MCCAULEY
JAMES MICHALOS
N. W. MORGAN
C. T. MORRIS (E)
N. M. NEWMARK
J. C. NICHOLS
T. G. O'NEIL
R. E. PECK
G. H. PERKINS
A. G. RANKIN
C. A. ROBERTS
G. E. ROBINSON
G. W. SALMON
C. H. SANDBERG
T. C. SHEDD
L. L. SHIREY
A. E. SMITH
H. F. SMITH
J. E. SOUTH
G. L. STALEY
H. C. TAMMEN (E)
W. M. THATCHER
E. K. TIMBY
H. T. WELTY (E)
A. R. WILSON (E)
W. M. WILSON (E)
L. T. WYLY
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revision of Specifications for Steel Railway Bridges, submitted for adoption and publication in the Manual ..... page 506

   Revision of Rules for Rating Existing Iron and Steel Bridges, submitted for adoption and publication in the Manual ..... page 507

   Reapproval without change of Manual Material, submitted for adoption and publication in the Manual ..... pages 506–507

3. Specifications for use of high-strength steels.
   Final report, with revision of Specifications for High-Strength Steel, submitted for adoption and publication in the Manual ..... page 508

4. Stress distribution in bridge frames:
   (a) Floorbeam hangers;
   Progress in study, but no report.
   (c) Truss bridge research project.
   Progress report, presented as information ..... page 508

5. Design of steel bridge details.
Progress in study, but no report.

6. Preparation and painting of steel surfaces.
Progress report, presented as information ..... page 509

7. Bibliography and technical explanation of various requirements in AREA specifications relating to iron and steel structures.
Progress report, presented as information ..... page 535

8. Specifications for design of corrugated metal culverts, including corrugated metal arches.
Progress report, presented as information ..... page 550

10. Specifications for design of continuous bridges.
Final report, presented as information ..... page 553

THE COMMITTEE ON IRON AND STEEL STRUCTURES,
D. V. MESSMAN, *Chairman.*

AREA Bulletin 548, January 1959.

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), J. L. Beckel, R. P. Davis, A. R. Harris, J. F. Marsh, D. V. Messman, C. Neufeld, C. H. Sandberg.

Your committee submits for adoption the following recommendations with respect to the Manual:

Pages 15–1–1 to 15–1–43, incl.

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Page i of Table of Contents: Under Part 1, Sec. C, change the word "Alloy" to "High-Strength".

Page 15–1–4, Art. 8, Sec. A: For plate girders, change 125 ft to 130 ft, and for riveted trusses, change 100 ft to 130 ft.

Page 15–1–15, Art. 46, Sec. A: Substitute the following for the last sentence:

If the grip equals or exceeds 6 times the nominal diameter, the body shall be tapered from the head for a distance not less than 3.42 times the nominal diameter, but not more than 4¾ in. The body diameter at the head shall be $\frac{1}{32}$ in greater and where not tapered, $\frac{1}{64}$ in less than the nominal diameter.

Page 15–1–27, Art. 110, Sec. A: In the second paragraph, first line, delete the word "plate."

Pages 15–4–1 to 15–4–3, incl.

SPECIFICATIONS FOR THE DESIGN OF RIGID-FRAME STEEL BRIDGES

Reapprove without change.

Pages 15–6–1 and 15–6–2

INSTRUCTIONS FOR THE MILL INSPECTION OF STRUCTURAL STEEL

Reapprove without change.

Pages 15–6–2 to 15–6–4, incl.

INSTRUCTIONS FOR THE INSPECTION OF THE FABRICATION OF STEEL BRIDGES

Reapprove without change.

Pages 15–6–5 to 15–6–9, incl.

INSTRUCTIONS FOR THE INSPECTION OF BRIDGE ERECTION

Reapprove without change.

Pages 15–7–1 to 15–7–3, incl.

CLASSIFICATION OF RAILWAY BRIDGES

Reapprove without change.

Pages 15–7–3 to 15–7–8, incl.

RULES FOR RATING EXISTING IRON AND STEEL BRIDGES

Adopt the revisions to Art. 14, pages 15–7–6 to 15–7–8, incl., as published on page 701, Vol. 59 of the Proceedings, except that the coefficients preceding the term l^2r^3 in the compression formula for high-strength steel up to and including 1 in thick shall be changed from 0.66 to 0.62 for riveted ends and from 0.86 to 0.83 for pin ends; and for high-strength steel over 1 in thick, from 0.66 to 0.53 for riveted ends and from 0.86 to 0.70 for pin ends; and that the coefficients preceding the term l^2/b^2 in the compression formula in extreme fibers of rolled shapes, girders and built sections, subject to bending, shall be changed from 7.5 to 12 for high-strength steel up to and including 1 in thick and from 7.5 to 10 for high-strength steel over 1 in thick.

Page 15–M–3

FUSION WELDING

Reapprove without change.

Page 15–M–20 and 15–M–21

TRACK ANCHORAGE ON BRIDGES AND SIMILAR STRUCTURES

Reapprove without change.

Page 15–M–30 to 15–M–33, incl.

METHOD OF SHORTENING EYEBARS TO EQUALIZE THE STRESS

Reapprove without change.

Report on Assignment 3

Specifications for Use of High-Strength Steels

E. S. Birkenwald (chairman, subcommittee), Ethan Ball, R. T. Blewitt, N. W. Morgan, N. M. Newmark, G. H. Perkins, L. L. Shirey, E. K. Timby.

At the last annual meeting of the Association, a specification was adopted for the use of high-strength steels.

Since then, a study was made of the column formulas and the formulas for compression in extreme fibers of rolled shapes, girders and built sections subject to bending, given in Art. 1, Sec. C, which indicates that the coefficients for the terms l^2/r^2 and l^2/b^2 are not consistent with the application of the secant formula in Appendix A, page 15–1–41 of the Manual.

To remedy this the following revisions should be made to the Manual:

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Page 15–1–39, Art. 1, Sec. C: For the coefficients preceding the l^2/r^2 term in the column formula for riveted ends, change 0.66 to 0.62 for materials up to and including 1 in in thickness and change 0.66 to 0.53 for materials over 1 in thick; for pin ends, change 0.86 to 0.83 for materials up to and including 1 in in thickness and change 0.86 to 0.70 for materials over 1 in thick.

For the coefficients preceding the l^2/b^2 term for the compression formula in extreme fibers of rolled shapes, girders and built sections subject to bending, change 7.5 to 12 for materials up to and including 1 in in thickness and change 7.5 to 10 for materials over 1 in thick.

Change the limit of the l/b value from a maximum of 40 to a maximum of 30.

A letter ballot has been taken and voted on favorably by the committee. It is recommended that the Association adopt this revision for publication in the Manual.

Unless the Association desires the committee to prepare design specifications for proprietary low-alloy steels, which cost as much or more and which do not provide yield point and working stresses as high, it is recommended that this Association assignment be terminated

Report on Assignment 4

Stress Distribution in Bridge Frames

(c) Model railway truss bridge

C. H. Sandberg (chairman, subcommittee), E. F. Ball, J. E. Bernhardt, E. S. Birkenwald, R. P. Davis, E. T. Franzen, J. M. Hayes, F. M. Masters, J. Michalos, N. M. Newmark, N. W. Morgan, G. L. Staley, L. T. Wyly.

Your committee submits the following report of progress.

The model truss bridge has been erected on Northwestern University property at Emerson and Maple Avenues in Evanston, Ill. A steel building has also been erected which encloses the bridge. The loading jacks are in place; however, the hydraulic system remains to be erected. Due to the lack of funds, G. M. Magee has volunteered to have his staff place the strain gages on the control end-post members which will be

tested first. It is hoped to have the hydraulic system in place and tests started in the first part of 1959.

The project is sponsored by Northwestern University, Association of American Railroads, Corps of Engineers, U. S. Army and Bureau of Public Roads. Numerous business firms have also contributed material, labor, and money. The project director is L. T. Wyly, professor of civil engineering, Northwestern University.

Report on Assignment 6

Preparation and Painting of Steel Surfaces

R. C. Baker (chairman, subcommittee), R. N. Brodie, A. R. Harris, D. L. Jerman, F. M. Masters, N. W. Morgan, R. E. Peck, G. H. Perkins, A. G. Rankin, C. A. Roberts, G. W. Salmon, A. E. Smith.

This is a progress report, submitted as information.

During the past year the director of research of the Steel Structures Painting Council, committee members, and representatives from the AAR research staff inspected paint tests on two bridges of the Missouri Pacific near Chester, Ill., three bridges on the Santa Fe near Kansas City, one bridge on the New York Central in Chicago near the AAR Research Center, one bridge on the Great Northern near Breckenridge, S. Dak., and one bridge on the Pennsylvania near Rayland, Ohio.

An additional test installation was started on the Chicago Great Western near Byron, Ill., with the purpose of evaluating the performance of various protective coating systems on the top flanges of deck plate girders.

The committee is continuing its cooperation with the Steel Structures Painting Council on laboratory and fields tests to determine the best painting and cleaning practice to use over welded joints, the possible use of iron oxide produced by the rusting of steel in the formulation of a suitable paint for such surfaces and the comparison of hot sprayed coatings with those applied by conventional methods.

The progress reports of the Steel Structures Painting Council on "Brine-Resistant Bridge Paints" and "Protecting Top Flanges of Bridges", presented hereinafter as Appendix A and Appendix B, respectively, give a more complete description of some of the studies being conducted.

Appendix A—Brine-Resistant Bridge Paints

By John D. Keane* and Joseph Bigos**

A. DIGEST

This test was conducted by the Steel Structures Painting Council in cooperation with the Missouri Pacific Railroad through arrangements made by the Association of American Railroads. The purpose of the test is to provide information toward the solving of one of the railroad industry's greatest maintenance problems—corrosion caused by brine drippings on steel structures. In this test, two bridges were cleaned and painted with a number of paint systems in an endeavor to obtain satisfactory methods of painting the floor systems of railroad bridges exposed to brine drippings.

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** Formerly director of research, Steel Structures Painting Council, presently connected with Applied Research Laboratory, U. S. Steel Corporation, Monroeville, Pa.

One bridge was sandblasted, and a number of systems applied; the other bridge was steam cleaned and wirebrushed before painting. The paint systems on the two types of surfaces are not all the same, but the control systems and several others are duplicated on both bridges. Application was completed October 2, 1953, and a touch-up of the steam-cleaned wire-brushed bridge was carried out in 1956. Five inspections have been made—in September 1954, June 1955, April 1956, July 1957, and September 1958.

The experience gained from this test after five years of exposure is that several systems afford excellent protection over sandblasted surfaces and that it may also be possible to do a good job of bridge maintenance under severe brine conditions without sandblasting if a careful job is done on surface preparation and if follow-up repairs are made as indicated by periodic inspections.

On sandblasted areas, a vinyl system, a chlorinated rubber, an alkyd, an asphalt mastic, and a phenolic all remained in excellent condition. Several were in fairly good condition, including 2 phenolics, 2 coal tar mastics, a vinyl, an alkyd phenolic, and a styrene-butadiene copolymer coated section. Sections showing some deterioration included the oil-base control system, a Neoprene section, one of the phenolics and an amine catalyzed epoxy. An epoxy ester exposure was interrupted by fire.

On the hand-cleaned bridge the low-cost rust-preventive greases were badly deteriorated the first year. The asphalt oil with bridge cement topcoat deteriorated badly the second year. On the remainder of the bridge, most of the sections where brine had splashed were in poor condition at the 1956 (three-year) inspection, particularly around rivet heads, fillets and sharp corners on the floor beams, including not only the low-cost rust preventives but also the proprietary vinyls and alkyd-phenolics as well as the oil-base control. The bridge was carefully retouched in the bad areas in 1956. After more than two years of additional exposure the paint systems are now in excellent condition, and indicate they will give several more years of additional service.

B. INTRODUCTION

The object of this test is to evaluate paint systems over sandblasted and over steam-cleaned wire-brushed surfaces for their ability to resist corrosion due to brine drippings from railroad refrigerator cars.

Details of the test plan and preparation are given in a previous report.[1] The present report is an account of the work and conclusions since that time.

Perhaps the most important and severe factor in determining the life of railroad bridges is the presence of brine drippings, which expose the floor systems and lower chords of bridges to a very corrosive environment. As the ice melts in the customary bunker type of refrigerator car, the drippings flow out through drain spouts as a salt-water solution, which is dripped and sprayed on steel structures along the right-of-way. Because of the seriousness of the resultant corrosion problem, much study has been devoted to satisfactory painting of railroad structures exposed to brine.

Other approaches to a solution of this problem have also been investigated by the railroads; it has been found, for example, that the addition of corrosion inhibitors to the ice in the bunker would drastically decrease the corrosiveness of the brine drippings. Collecting of the brine for periodic discharge has also been suggested, and eventually mechanical refrigeration may eliminate the problem. Since these other corrective or preventive measures will not be materially effective for many years, it is important that reliable protective coatings be found for protection of the bridges and other structures along the right-of-way.

[1] See "References" at end of this report.

The painting of railroad bridges has always been a serious problem, but the rapidly increasing costs of maintenance painting necessitates a careful analysis of the methods of protection to reduce annual painting costs to a minimum. The tests described in this paper, as well as others undertaken by the SSPC and by the railroads, are believed to be significant in showing the way to more efficient painting and to the utilization of more resistant coating materials of longer life expectancy. It is believed that the experience being obtained on this test will be a useful supplement to the Steel Structures Painting Manual.[2, 3] This manual includes a comprehensive summary of good painting practices in the painting of railroad bridges and outlines in detail the available specifications for the surface preparation, pretreatment and application of paint in the shop and in the field.

C. DESCRIPTION OF TEST

This field test was conducted on the floor system of two bridges of the Missouri Pacific Railroad located within 12 miles of each other in the vicinity of Chester, Ill., approximately 50 miles south of St. Louis, Mo. The Missouri Pacific supplied the labor and material for the test. These bridges were selected because of heavy refrigerator car traffic, which had led to considerable trouble in the past.

Prior to the painting of these bridges, it was found that the most severe attack occurred on the floorbeams, principally between the truss and the stringers; the stringers were attacked principally on the top flanges and the outer surfaces. Only minor localized attack occurred on the surfaces of the stringers and the floorbeams between the rails. Fig. 1 shows a typical condition after cleaning, illustrating that a considerable portion of the steel surface had been attacked by brine corrosion. On both bridges the remaining paint had very poor adherence to the metal and much of it was undercut by rust. A futile attempt to retard corrosion had been made with paint which was applied to the rusted web of the floorbeam, but which failed to stop corrosion underneath the paint.

Two methods of surface preparation were selected for these structures: blast cleaning on Bridge 69 and steam and hand cleaning on Bridge 94. There is no doubt that blast cleaning is the best method for obtaining maximum paint life on such structures. It is, however, an expensive operation and the individual railroad must decide for itself whether it is an economical one. As described in Chapter 2 of the Steel Structures Painting Manual, there are many methods of blast cleaning, but the principal one in field use on bridges is direct pressure sandblasting. On the hand-cleaned bridge, steam cleaning was used before wire brushing in order to remove the brine which had soaked into the rust, cracks, crevices and the old paint.

Bridge 69—Sandblasted

Bridge 69 over the Okaw River consists of one 150-ft through truss span and one 216-ft through truss draw span which is not opened. The 150-ft span contains 7 floorbeams and the 216-ft span includes 10 floorbeams. Diagrams of the test plan are shown in Figs. 2 and 8, and the bridges are pictured in Figs. 3, 4 and 9.

The floor system of the 2 through truss spans on Bridge 69 is divided into 15 test areas, as shown in Fig. 2, the division points being the center of each panel. These areas are lettered A through O. Supplementary tests were also made on areas which were in somewhat more sheltered locations, G4, H4, H5, I4, I5, J4, J5 and N5.

From previous experience on the bridge it was known that the corrosive attack from brine drippings is much greater on the west side of the spans. Therefore, test areas

include the west ends of the floorbeams from the west line of stringers outward, west face of stringers including top and bottom surfaces of top flanges, and lower panel laterals outward from the west line.

Bridge 69 was sandblasted. In the course of removing the rust and paint, which had been overcoated a few years previously by a grease type of coating, it was necessary to blast to a grade almost equal to white metal, as described in SSPC–SP6–52T "Commercial Blast Cleaning." Some Ottawa silica sand was used, but most of the work done with Meramec River sand, which had to be dried before use. Fig. 7 shows the oil-fired rotary kiln used for drying the sand, and details are given in a previous paper.[1]

Each test area is approximately 250 to 300 sq ft. Pretreatment SSPC–PT2–53T, "Basic Zinc Chromate, Vinyl Butyral Wash Coat Pretreatment" was applied as soon as possible after sandblasting to the diagonal half of certain test areas. The purpose of this diagonal division of the floorbeams was to have some indication of the effect of wash primer, but, due to the localized attack of the brine, deterioration tended to occur wherever the brine struck, regardless of the presence or absence of the pretreatment. Similarly, these particular areas were also divided diagonally in the other direction, to test the effectiveness of aluminum versus black topcoats, but no conclusion can be drawn due to the localized nature of the attack.

Various paint systems were applied, including combinations of vinyls, phenolics, alkyds, coal tar mastics, chlorinated rubbers, styrene-butadiene copolymer resins, dehydrated castor oil alkyd, epoxy resins, and Neoprene coatings. All paints were applied in compliance with the SSPC–PA1–53T "Shop, Field and Maintenance Painting" and paint records were kept on Council forms.

Bridge 94—Hand and Steam Cleaned

Bridge 94 across the St. Mary's River consists of one 150-ft through truss span identical with the 150-ft span in Bridge 69. It is located 12.5 miles south of Bridge 69 and contains 7 floorbeams. Traffic and environmental conditions are the same for both bridges; approaches are open deck timber trestles and the first and last floorbeams are exposed. Test areas on this bridge have been lettered P through V. Fig. 8 is a sketch of the test areas and Fig. 9 is a picture of the bridge.

This bridge was in extremely bad condition due to neglect over a number of years. On this bridge, as on Bridge 69, the west side was selected for the test area because of exposure to sunlight as well as slightly worse corrosion than on the east side.

As described in the previous report,[1] the surface of this bridge was prepared for painting by applying a heavy dose of hot detergent solution (Oakite 92) and flushing off with hot water (steam cleaning), as shown in Fig. 10. Next the paint and rust scale were removed by chipping, scraping and wire brushing, followed by a final rinse with hot water. Cracks and crevices were blown out with air prior to painting. The first steam cleaning was used in order to remove residues of brine which had soaked into the rust and cracks, whereas the final steam cleaning was carried out to remove the oil and brine deposited during the cleaning period.

As on Bridge 69, the Council Pretreatment SSPC–PT2–53T, "Basic Zinc Chromate, Vinyl Butyral Wash Coat Pretreatment" was applied to diagonal halves of each test area, and aluminum or black topcoats were placed on the opposite diagonal halves, making four test sections in all.

Following the pretreatment, paint systems were applied in accordance with SSPC–PA1–53T "Shop, Field and Maintenance Painting." These systems included combina-

tions of phenolics, alkyds, vinyls, asphalt oil, greases and proprietary materials, as listed in Table 2. As a control, a standard oil-base paint system of the Missouri Pacific was included on each bridge.

D. TEST RESULTS

Inspections of these two bridges have been made annually, with the last inspection being held in September 1958. In general the condition of the sandblasted bridge was excellent. The steam-cleaned wire-brushed bridge is now also in excellent condition, but this bridge was retouched in 1956.

Ratings for rusting were made in accordance with ASTM Designation D 610–43 "Standard Method of Evaluating Degree of Resistance to Rusting Obtained with Paint on Iron or Steel Surfaces." According to this commonly accepted rating method, a score of 10 is considered perfect, and 0 indicates complete failure. A rating of 8 usually indicates that spot cleaning and spot priming the surface will suffice for repainting, while a rating of 6 indicates that complete cleaning of the surface prior to repainting is necessary. Ratings of 4 or below indicate that complete removal of the coating is required before repainting; such surfaces are so badly rusted that the numerical values below 4 have no great significance. Photographic standards tend to keep this rating method objective and fixed.

Bridge 69—Sandblasted

Paint systems on the sandblasted Bridge 69 were given ratings representing the reading by the members of the inspection party. Unless otherwise indicated, the rating represents an average between the condition of the stringer and the floorbeam. Complete inspection results are shown in Table 1. Ratings shown in the paragraph below represent the condition of the floorbeam only in the September 1958 inspection.

Of the vinyls, an aluminum vinyl system (B), SSPC—Paint 8—55T "Aluminum Vinyl Paint", over the wash primer is in almost perfect condition but shows some rust due to bad cleaning at crevices only (Rating 9.0). On area (A), a wash primer, two coats of red lead vinyl, topcoated with black vinyl (SSPC Paint 106) is doing fairly well (8.0), having some rust on the side of a few rivets and some breakdown due to poor cleaning of scale at crevices.

A chlorinated rubber system (C) has very good appearance (9.0) with only a few rivet heads slightly rusted: A styrene-butadiene copolymer system (D) is flaking off with very tiny rust breakthrough on floorbeam (8.0). Where there is a thicker film on the flange top, the paint system is doing better. This system had had some tiny specks of rust when first inspected in 1954, but has not deteriorated much since then.

The red lead phenolic system topcoated with aluminum and black phenolics (E) had some spots of scale on the floorbeam (8.0). This system had no rust spots at all until the 1956 inspection.

A red lead, zinc chromate, zinc oxide, alkyd-phenolic (two coats) with aluminum and black phenolic topcoats (F) is doing well (8.5), showing only a few tiny rough spots on the stringer and floorbeam (possibly imbedded sand).

On area (H) the red lead, zinc chromate—mica—castor oil alkyd (two coats) with the aluminum and black (SSPC Paint 103) phenolic topcoats is slightly better (8.5+) than the above. Only two rivets were slightly rusted and this was the first deterioration to show since painting.

A zinc chromate—red lead—iron oxide—mica—phenolic (I) (SSPC Paint 10) top-

coated with aluminum and black phenolics had a bad area at crevice of the stiffener, some blisters and rust spots (8⁻).

Red lead—iron oxide—phenolic (SSPC Paint 6) under aluminum and black phenolic finish coat (J) rated 8.5 and a coal-tar mastic system (K) rated 8.5, having some rust scale. Another coal-tar mastic system (L) of two coats rather than three rated 7.5 due to rust on rivet heads, stiffener, web and edge of flange.

A two-coat system (M) which rated an 8.5 had SSPC Paint 10 as the first coat (Same as Area I) and an asphalt gilsonite mastic as topcoat. There is no rust, although the topcoat appears to be losing adhesion to the primer.

The early type of amine-catalyzed epon system on area N showed poor durability (6⁻) on the floorbeam.

Evaluation of the epoxy ester coating system on area (O) was discontinued because of a fire which damaged this coating.

The control system (Beam G)—containing red lead, lead chromate, iron oxide and extender in a linseed oil vehicle in the primer (two coats of which were applied) and a carbon and linseed oil finish coat—has some slight pinholes that are apparently due to sand. The floorbeam has rust blisters and rates 7.5.

Bridge 94—Hand and Steam Cleaned

On the steam- and hand-cleaned bridge, No. 94, serious deterioration of the grease rust preventives was noted as early as six months after application. During the second year serious rust blistering occurred on the asphalt oil system with severe undercutting by rust. By April 1956 considerable breakdown had occurred on other vital areas where brine contact was continuous. As previously mentioned this bridge was then carefully retouched in the bad areas.

In September 1958, two years after this repair, all systems were doing well except for two proprietary materials which show the beginning of flaking and chalking. Both P and Q were in very good condition, although Q had been better than P at the time of retouching in 1956.

Vinyl system S with the wash primer and red lead vinyl primer was the best on the bridge and considerably better than vinyl T with the proprietary primer. The control system on this bridge (Beam R) rates about 8.5. Ratings and comments are summarized in Table 2.

E. SUPPLEMENTARY TESTS

Portions of both bridges not included in the main test were used in an auxiliary study to evaluate special materials. The paint systems are listed in Tables 1 and 2 along with their ratings as determined by subsequent inspections. These sections received the same surface preparation as the bridge to which they were applied. Due to the sheltered location of these areas, they show relatively little deterioration, and no conclusions have yet been drawn regarding these systems.

The tops of the upper flanges of the turntable stringers on Bridge 69 were blast cleaned and primed with a proprietary adhesive primer. The west stringer had one coat of a proprietary rubber film. The east stringer had one coat of a polyvinyl chloride film, with a second layer of rubber film on top of the center half. All films were wrinkled and torn because of traffic before the adhesive had time to cure.

The east part of the web of the floorbeams in area L was blast cleaned, and one half of the area primed with the film primer, the other half unprimed. A rubber film

was applied to half the test area and a polyvinyl chloride film was applied to the other half in such manner that both films were tested over bare steel and over primed steel.

In September 1958 the films between the ties were gathered together and under the ties were worn away; film on the web was still in fairly good condition.

Additional areas on the east side of Bridge 94 were painted at the time the rest of the test was retouched in 1956. Although a polyurethane and a vinyl mastic were in fairly good condition two years later, a vinyl cocoon was in poor condition; these exposures cannot be compared with the main test on the west side of the bridge because of the less severe attack on the east side.

F. CONCLUSIONS

Based on the average rating for the various test sections the following conclusions are drawn from observations made to date.

1. With sandblasting it is possible to do a good job of bridge maintenance under severe conditions.

2. A fairly wide choice of systems applied to a sandblasted surface will provide good protection in severe brine conditions, including properly formulated vinyl, alkyd, phenolic, coal tar, asphalt, and chlorinated rubber paints.

3. It is possible to do a good job of bridge maintenance without sandblasting if a careful cleaning job is done and if careful periodic inspection and repair follow.

4. Further observation of these bridges should be made in order to yield necessary data on paint life, frequency of touch-up and over-all cost per square foot per year for adequate protection. It is often difficult to detect undercutting on the heavy mastic or oil protectives until after serious amounts of rust have formed.

F. ACKNOWLEDGEMENT

The tests described in this report were carried out under the guidance of AREA Committee 15 under its Assignment 6 (subcommittee chairman, R. C. Baker). Advice and direction were also furnished by the Research Committee of the SSPC, J. O. Jackson, chairman, and by the AAR, E. J. Ruble, Association representative. The Missouri Pacific Railroad furnished labor and materials, and was responsible for the execution of the test plan under the direction of R. E. Peck, bridge engineer. W. L. Short, assistant engineer, played a most important part in the selection of the bridge, choice of test areas, the procurement and application of materials and in the frequent observation of the test site.

REFERENCES

1. AREA, Proceedings, Vol. 55, pp. 1021–1042 (1954).

2. Steel Structures Painting Manual, Vol. 1, "Good Painting Practice."

3. Steel Structures Painting Manual, Vol. 2, "Systems and Specifications."

TABLE 1—MISSOURI PACIFIC BRINE DRIPPINGS TEST

Bridge 69—Surface Preparation by Sandblasting

Painted, September 1953

Test Area	*Pretreatment*	*1st Coat*	*2nd Coat*	*3rd Coat*	*Inspection*		
					Date	*Rating*	*Remarks*
A	Wash Primer	Red lead vinyl MIL-P-15929A	Same	Black vinyl SSPC-Paint 106	9/54	10.0	Perfect condition
					6/55		OK
					4/56		OK—Couple of rivets rusty
					7/57	8.8	Stringer better than floorbeam (on most of these test areas). Some rust on side of a few rivets. Some breakdown due to poor cleaning of scale.
					9/58	8.0	Floorbeam. 10 stringer.
B	Wash Primer	Aluminum vinyl SSPC-Paint 8	Same	Same	9/54	10.0	Perfect condition
					6/55		OK
					4/56		OK—Couple of rivets rusty
					7/57	9.1	Almost perfect, except for bad cleaning at crevices only.
					9/58	9.0	Floorbeam. 10 stringer.
C	Wash Primer	Red lead chlorinated rubber	Gray chlorinated rubber	Black chlorinated rubber	9/54	10.0	Perfect condition
					6/55		OK
					4/56		OK
					7/57	9.5	Very good appearance. Few rivet heads slightly rusted.
					9/58	9.0	Floorbeam. 9.5 stringer.
D	Wash Primer on ½ floorbeam only	Iron oxide, zinc chromate, styrene butadiene copolymer and phenolic varnish	Aluminum, styrene butadiene copolymer	Aluminum, styrene butadiene copolymer	9/54		A few tiny specks of rust on floorbeam, otherwise perfect.
					6/55		OK
					4/56		OK—One bad area on web
					7/57	7.1	Incipient flaking off and very tiny rust break-through on floorbeam. Flange top OK (thicker film).
					9/58	8.0	Floorbeam. 10 stringer.
E	None	Red lead phenolic TT-F-86a, Type IV	Same	Aluminum and black phenolics**	9/54	10.0	Perfect condition
					6/55		OK
					4/56		OK—One bad area. Rust on top angle.
					7/57	8.2	Some spots of scale on floorbeam.
					9/58	8.0	Floorbeam. 10 stringer.
F	Wash Primer on ½ floorbeam only	Red lead, zinc chromate, zinc oxide alkyd, phenolic; I.I.A.*** 183	Same	Aluminum and black phenolics**	9/54	0	Perfect condition
					6/55		OK
					4/56		OK—Some breakdown on top web by flange
					7/57	9.2	Very good. Few tiny spots on stringer and floorbeam (possibly imbedded sand).
					9/58	8.5	Floorbeam. 10 stringer.

TABLE 1 (Continued)

Test Area	Pretreatment	1st Coat	2nd Coat	3rd Coat	Inspection		
					Date	Rating	Remarks
G*	Wash Primer on ½ floorbeam only	Red lead, iron oxide, lead chromate and extender in linseed oil	Same	Black linseed oil topcoat	9/54		This is the control system. Slight rusting on south side of floorbeam web.
					6/55		Slight rusting on floorbeam web and considerable deterioration of topcoat. Fair amount of breakdown on web—south side and lateral bottom of stringer the worst on bridge.
					7/57	8.3	Some slight pinholes—apparently sand. Floorbeam has rust blisters.
					9/58	7.5	Floorbeam. 9.5 stringer.
G4	---	Zinc dust paint	Same	---	9/54		On stringer only; very slight rusting
					9/58		OK—On stringer only.
H	Wash Primer on ½ floorbeam only	Red lead, zinc chromate, mica, castor oil alkyd; L.I.A.*** 132	Same	Aluminum and black phenolics**	9/54	10.0	Perfect condition
					6/55		OK
					4/56		OK
					7/57	9.4	Almost perfect. wo rivets slightly rusted.
					9/58	8.5+	Floorbeam. 10 stringer. Slight rust on stiffener crevice.
H4	---	Proprietary chlorinated rubber paint	Proprietary neoprene paint	---	9/54	10.0	On stringer only. Perfect condition.
					4/56		Side tests all OK except for Neoprene considerably rusty over all. Film no fundamental deterioration.
					7/57		Neoprene chalking. Some pin point rust.
					9/58	7.	Stringer only.
H5	---	Lead suboxide linseed oil paint	Same	Aluminum phenolic	9/54	10.0	Perfect condition
					7/57		OK
					9/58	10.0	Stringer only.
I	Wash Primer on ½ floorbeam only	Zinc chromate, red lead, iron oxide, mica, phenolic; S.D.C. 251 (SSPC-Paint 10)	Same	Aluminum and black phenolics**	9/54	10.0	Perfect condition.
					6/55		OK
					4/56		OK
					7/57	8.7	Floorbeam 9.0. Crevice at stiffener bad. Some blisters and bad rust spots.
					9/58	8.	Floorbeam. 9.5 stringer.
I4	---	Sanitary Dist. of Chicago No. 251 (SSPC-Paint 10) Phenolic primer	Asphalt Mastic	Asphalt Mastic	9/54	10.0	On stringer only; perfect condition.
					7/57		On stringer only; OK.
					9/58	10.0	On stringer only.
I5	---	Proprietary chlorinated rubber paint	Same	Same	9/54	10.0	On stringer only; perfect condition.
					7/57		OK
					9/58	10.0	On stringer only.

TABLE 1 (Continued)

Test Area	Pretreatment	1st Coat	2nd Coat	3rd Coat	Inspection		
					Date	Rating	Remarks
J	Wash Primer on ½ floor-beam only	Red lead, iron oxide, phenolic, Ohio Riv. Div. #512 (SSPC-Paint 6)	Same	Aluminum and black phenolics**	9/54	10.0	Perfect condition.
					6/55		OK
					4/56		OK
					7/57	8.9	----------
					9/58	8.5	Floorbeam. 10 stringer.
J4	----------	Chlorinated rubber paint	Neoprene paint	----------	9/54	10.0	On stringer only; perfect condition.
					9/58	10.0	On stringer only; perfect condition.
J5	----------	Corps of Engineers CE-512 (SSPC-Paint 6) Red lead iron oxide phenolic paint	Coal tar mastic	Coal tar emulsion	9/54	10.0	On stringer only; perfect condition.
					9/58	10.0	On stringer only; perfect condition.
K	Wash Primer on ½ floor-beam only	Coal tar mastic	Same	Coal tar emulsion	9/54	10.0	Perfect condition.
					6/55		OK
					4/56		OK—Some breakdown at rivet heads.
					7/57	8.7	Some rust scale. Crack on web of stringer.
					9/58	8.5	Floorbeam. 9.5 stringer.
L	Wash Primer on ½ floor-beam only	Coal tar mastic	Coal tar emulsion	None	9/54	10.0	Perfect condition.
					6/55		OK
					4/56		OK—Some breakdown at rivet heads.
					7/57	7.7	Some rust scale. Rivet heads fairly bad, also stiffener and web.
					9/58	7.5	Floorbeam. 10 stringer. Peeling at edge of flange.
M	Wash Primer on ½ floor-beam only	Same primer as on area I	Asphalt, gilsonite mastic	None	9/54	10.0	Perfect condition.
					6/55		OK
					4/56		OK
					7/57	8.7	Coating appears to be deteriorating, although very little rust.
					9/58	8.5	Floorbeam. 10 stringer. Primer intact, but topcoat peeling in spots.
N	Wash Primer on ½ floor-beam only	Red lead Epon (Amine catalyzed Ep	Same on coatings)	Gray Epon	9/54	10.0	Perfect condition.
					6/55		Some chalking, no rusting.
					4/56		OK—Lots of chalking.
					9/58	6.—	Floorbeam. 9.5 stringer.
N5	----------	Asphalt Mastic	None	----------	9/54	--------	On stringer only; perfect condition.
					9/58		Not rated.

TABLE 1 (Continued)

Test Area	Pretreatment	1st Coat	2nd Coat	3rd Coat	Inspection		
					Date	Rating	Remarks
O	Wash Primer on ½ floorbeam only	Zinc chromate epoxy ester primer	Gray epoxy ester	Gray epoxy ester	9/54		Perfect condition except for loss of gloss and mild chalking of the gray topcoat on horizontal surfaces.
					6/55		Some chalking, no rusting.
					4/56		Some breakout on floorbeam. (Fire on trestle approach damaged this test area.)
					9/58		Not rated—fire damage.

*Indicates control system. (This same primer tested on east end of floorbeam in area K with aluminum phenolic topcoat.)
**Aluminum phenolic— 2 lb Aluminum paste in 1 gal phenolic varnish per Federal Specification TT-V-119. Black phenolic per Ohio River Div. C.E., No. 506 (SSPC-Paint 103). Aluminum phenolic applied ½ floorbeam; black to remainder and stringer.
***Lead Industries Association.

TABLE 2

Bridge 94—Surface Preparation by Chipping, Scraping, Wirebrushing and Steam Cleaning, Painted September 1953, Retouched June 1956

Test Area	*Pretreatment*	*1st Coat*	*2nd Coat*	*3rd Coat*	*Inspection*	
					Date	*Remarks*
P	Wash primer on ½ floorbeam only	Red lead, linseed oil, litharge TT-P-86a, Type I, plus 2 lb litharge/gal	Red lead phenolic TT-P-86a, Type IV	Aluminum and black phenolics	9/54	Excellent, no breakdown
					3/55	Rust scale several spots on south floorbeam
					6/56	Retouched—south face only
					7/57	OK. About 9+
					9/58	8 floorbeam. 10 stringer.
Q	Wash primer on ½ floorbeam only	Zinc chromate, iron oxide, linseed oil, alkyd primer	Zinc chromate, iron oxide phenolic	Aluminum and black phenolics	9/54	Excellent condition except for one spot of rust scale ⅛″ in diameter on web of floorbeam
					3/55	Same as P but not as bad
					6/56	Retouched
					7/57	OK. About 9+
					9/58	8.5 floorbeam. 10 stringer.
R*	Wash primer on ½ floorbeam only	Red lead, iron oxide, lead chromate extender in linseed oil	Same	Black linseed oil topcoat	9/54	Web of floorbeam badly broken down. Aluminum on one half of floorbeam performing better than black linseed oil topcoat. Some breakdown on lateral. Stringer in good condition except for slight rusting on top surface of bottom flange.
					3/55	Scale floorbeam South
					6/56	Retouched
					7/57	OK. About 9.5
					9/58	8.5 floorbeam. 10 stringer.
S	Wash primer	Red lead vinyl MIL-P-15929A	Red lead vinyl	Black vinyl SSPC-Paint 106	9/54	Nearly perfect condition except for trifle of rust on stiffener of floorbeam.
					3/55	OK, Slight scale on stiffener. Some scale on north web and stringer
					6/56	Retouched
					7/57	OK. About 9
					9/58	9.5 floorbeam. 10 stringer.
T	Wash primer on ½ floorbeam only	Proprietary vinyl primer	Red lead vinyl MIL-P-15929A	Black vinyl SSPC-Paint 106	9/54	Floorbeam perfect except for bottom of stiffener where rust scale is forming. North side of floorbeam and stringer perfect.
					3/55	Similar to S
					6/56	Retouched
					7/57	OK, About 9+
					9/58	8 floorbeam. 9 stringer.
U ½ stringer area	None	Rust-preventive grease #1	None	None	9/54	Flaking off of dried coating very bad over entire web area of stringer. Considerable rust on bottom flange angle of stringer.

TABLE 2 (Continued)

Test Area	Pretreatment	1st Coat	2nd Coat	3rd Coat	Inspection	
					Date	*Remarks*
					3/55	Bad condition on stringer. Flaking and scale starting on bottom flange.
					6/56	Retouched
					7/57	OK, About 8
					9/58	8—slight flaking on stringer flange.
U ½ stringer area and floorbeam	None	Rust-preventive grease #2	None	None	9/54	Bad scaling and rusting on south side of floorbeam exposed to brine spray; large areas scaled and scale fallen off. Lower flange of stringer showing rust scale. Rust scaling taken place on lateral. Stringer web protected from sunlight and brine and in good condition.
					3/55	Bad scale on south floorbeam. Checking and flaking on stringer.
					6/56	Retouched
					7/57	OK, About 8
					9/58	8.5 floorbeam.
V	None	Asphalt oil	Bridge Cement (1 month later)	None	9/54	In perfect condition except for several tiny spots of rust caused by damage from flying stones.
					6/55	Serious rust blistering, indicating severe undercutting by rust. South floorbeam same as north.
					6/56	Retouched
					7/57	OK, About 8.5
					9/58	8 floorbeam, 9 stringer.
Q4 stringer only	Wash primer	Asphalt underbody coating	.....	.....	9/54	No breakdown visible; on stringer only
					3/55	OK
					6/56	Retouched
					7/57	OK, About 9.5
					9/58	Asphalt alligatored.
R4	.....	Proprietary oilbase primer	.....	Proprietary aluminum phenolic	9/54	No breakdown visible; on stringer only
					3/55	OK
					6/56	Retouched
					7/57	OK, About 9.5
					9/58	10 stringer only.
Q (east)	.....	Polyurethane system	.....	.....	6/56	Painted
					9/58	9.5 floorbeam, 10 stringer
R (east)	.....	Vinyl mastic system	.....	.....	6/56	Painted
					9/58	8.5 floorbeam.
S (east)	.....	Vinyl cocoon system	.....	.....	6/56	Painted
					9/58	6.0 floorbeam.

*Control System.

Fig. 1—Portion of bridge 69 after blast cleaning, showing attack by brine on rivets and plates.

Figure 2.

Principal Paint Test Areas
MoPac Bridge No. 69, Roots, Ill.

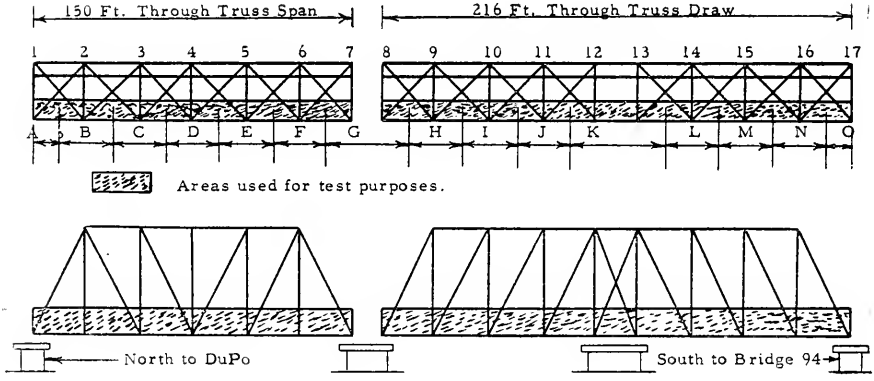


Fig. 3—Underside of bridge 69 across the Okaw River.

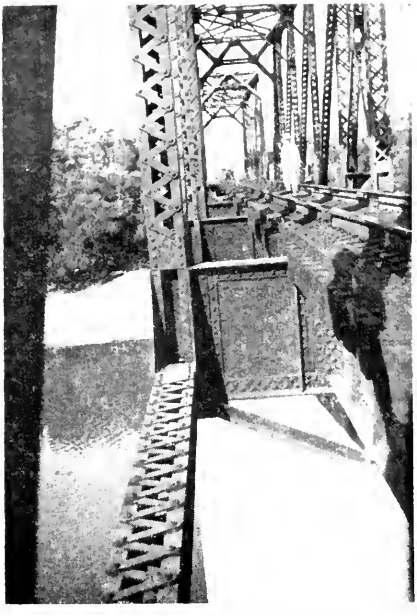


Fig. 4—Typical test areas on bridge 69 after two years of exposure.

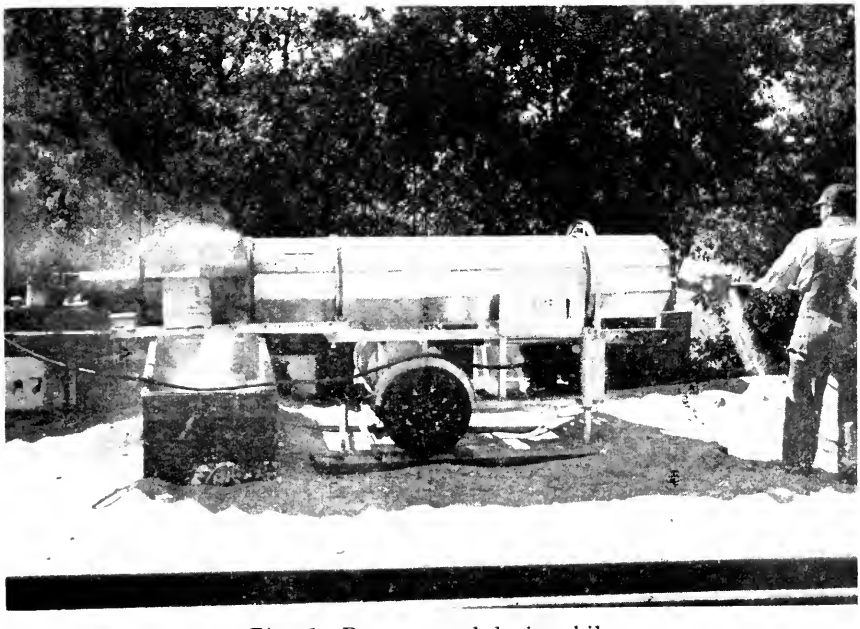


Fig. 5—Rotary sand drying kiln.

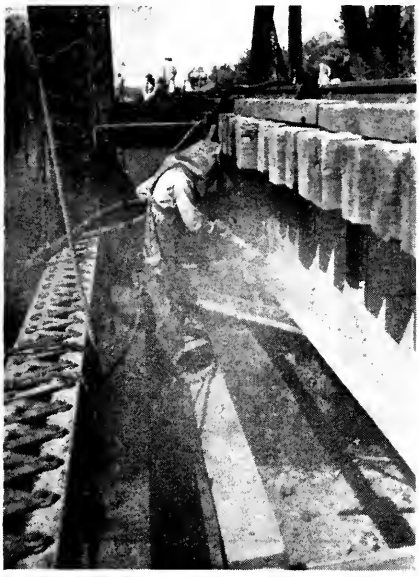


Fig. 6—Sandblasting bridge 69.

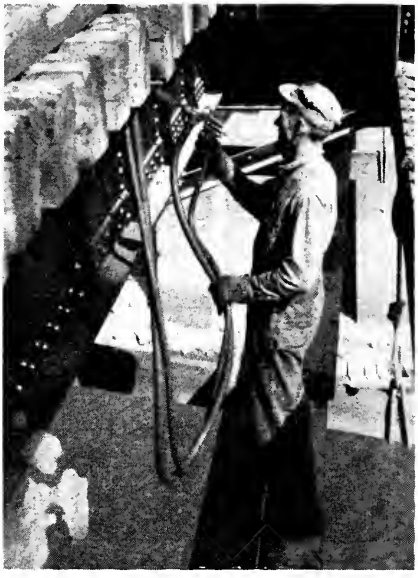
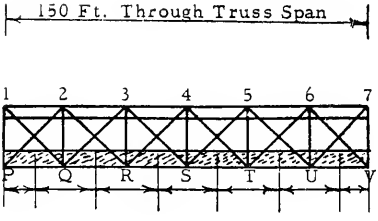
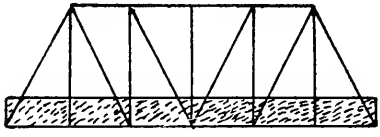


Fig. 7—Spraying coal tar emulsion, bridge 69.

Figure 8.

Principal Paint Test Areas
MoPac Bridge No. 94, Chester, Ill.





Bridge 94 across the St. Mary's River.

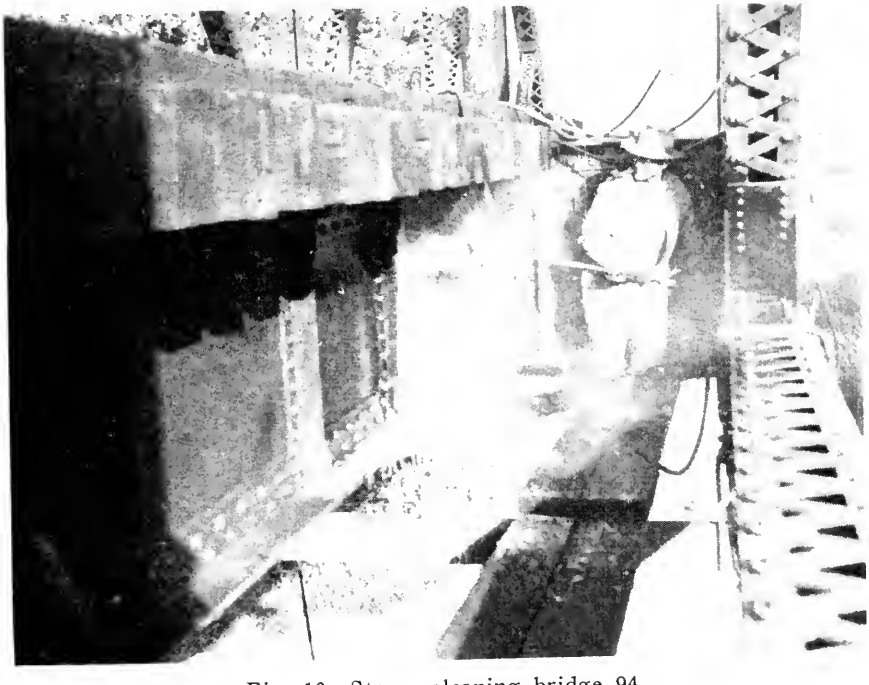
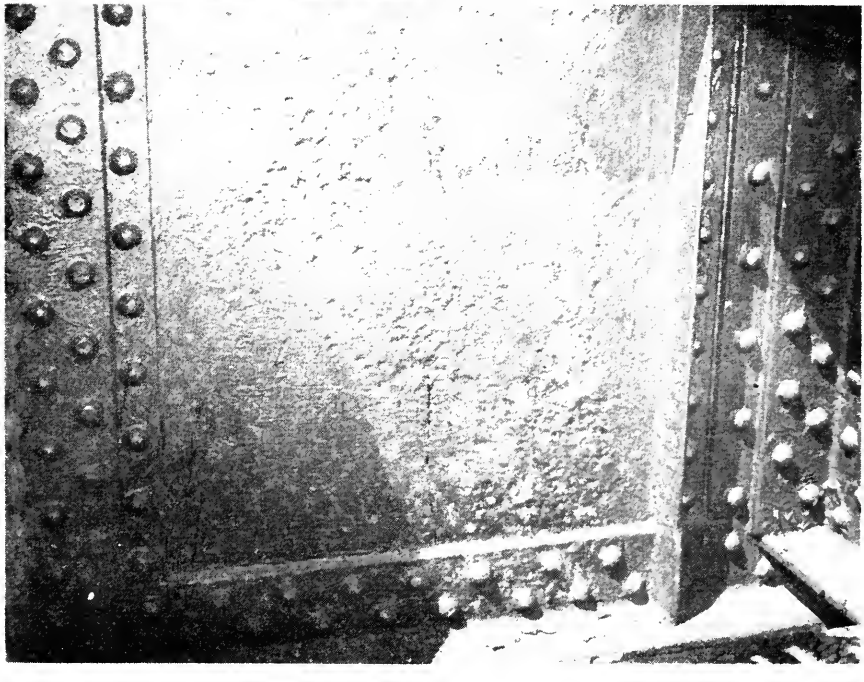


Fig. 10—Steam cleaning bridge 94.

Fig. 11 (left)—Hand chipping on bridge 94.

Fig. 12 (below)—Section U of bridge 94, showing failure of low-cost rust preventive after less than one year of exposure.



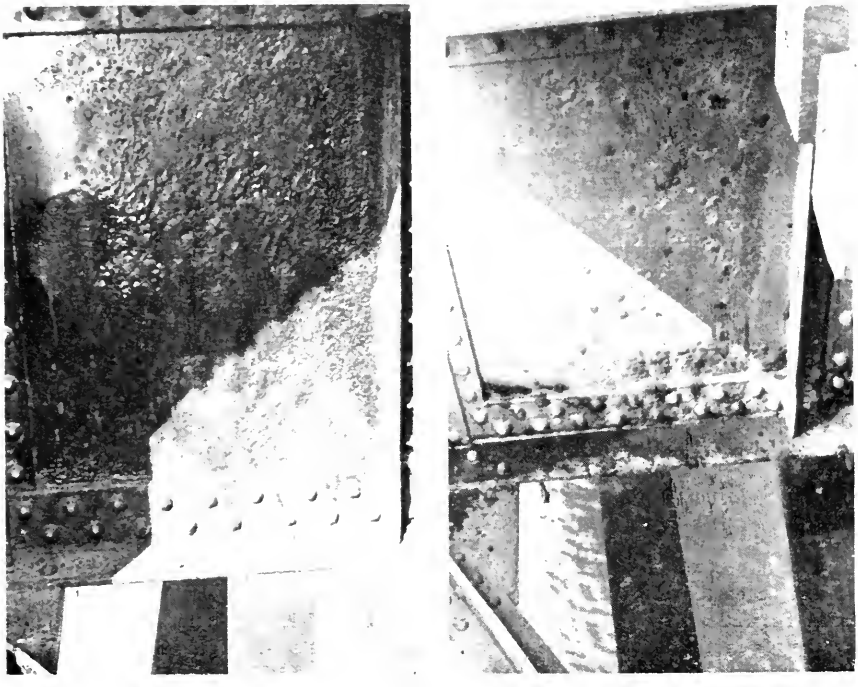
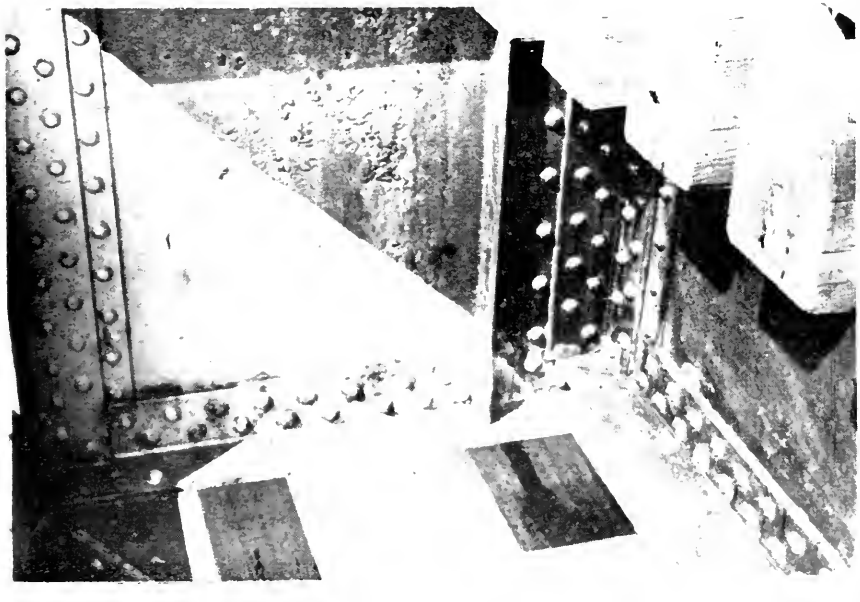


Fig. 13—Typical areas on bridge 94 prior to retouching (Sections T, R and Q).



Appendix B—Protecting Top Flanges of Bridges

*By John D. Keane

Summary

Over 20 durable steel-protective systems were applied to portions of the top flanges of a 786-ft bridge, where they will be exposed to severe attack from weathering, salt brine, abrasion and moisture. These protective systems were applied to both sand-blasted and hand-cleaned surfaces, chiefly in the fabricating shop, and included the following: metallizing, vinyl tapes, coal tar coatings, rust preventives, tie pads and paints based upon vinyl resins, epoxies, chlorinated rubber, zinc dust, Neoprene, inorganic zinc silicate, and various proprietary combinations. It is also planned to test these same systems in four other locations and environments by panel tests. Field tests were made of four of the best treatments previously found for painting over welds.

The test bridge is a shop-welded, open-deck girder with high-strength bolt field connections, located at Byron, Ill. These tests were made possible through the cooperation of the Pittsburgh–Des Moines Steel Company, the Chicago Great Western Railway and the Association of American Railroads.

The Problem

One of the most difficult structural steel coating problems is the protection of the top flanges of the beams on railroad bridges. These surfaces are directly beneath the timber ties and are subjected to a combination of brine drippings from refrigerator cars, abrasion from the ties, exposure to weathering and retention of moisture and contaminants. In many instances the rate of deterioration of the paint film over these cover plates and flange angles is accelerated in comparison with other parts of the structure, especially where there is a considerable amount of refrigerator car traffic. Often, the top cover plates or flanges are almost corroded through because of corrosion—erosion action. Because of the widespread interest of the railroads in this problem, a cooperative test was started on the Chicago Great Western Railway Bridge C–87–29 across the Rock River in Byron, Ill. This is a 12-span open-deck girder bridge, 786 ft long, of shop-welded design with all field connections made with high-strength bolts.

Shop fabrication and painting of the test areas were carried out August 17–29, 1958, at the Des Moines plant of the Pittsburgh–Des Moines Steel Company under the direction of G. W. Hall, plant manager. Field erection and painting of the test spans were carried out August 25–October 30 by the Mass Construction Company under the direction of J. M. Peterson, bridge engineer for the Chicago Great Western.

Test Plan

As shown in Fig. 1, 5 spans, each 70 ft long, were selected for testing of the protective systems. Two of these spans were sandblasted in accordance with SSPC–SP6–52T "Commercial Blast Cleaning", 2 were hand cleaned in accordance with SSPC–SP2–52T, "Hand Cleaning", and one was hand cleaned and painted with the specified oil base primer before application of the additional protective systems.

On the principal test, the experimental area was confined to the tops and edges of the top flanges, the tops being 16 in wide. In each case, identical protective systems were applied to the corresponding north and south girders of each test area. Welded stiffeners divide the web of each girder into 14 areas, each approximately 5 ft in length,

* Secretary and director of research, Steel Structures Painting Council.

as shown in Fig. 1. On this test, the top flanges directly above these 14 panels have been identified by the letters A through N from west to east. As shown on the diagram, a minimum test area for most of the systems consists of a 10-ft length on both the north and south girders. All systems (except metallizing, tie pads, and tape) were applied by brush application to the film thickness recommended by the manufacturer. Unless otherwise indicated in Table 1, the various coats were applied in the shop. Any damage which occurred during handling, transportation or erection was repaired in the field immediately after erection.

All of the systems used are outlined in Table 1, which also shows the location of test spans and the sequence of application of coats. A detailed record was made of the application of all shop and field protective systems. Twenty-six protective systems were used in the manner outlined, representing a cross section of those systems which have been used successfully in the past, which were recommended by the railroads and the SSPC Research Committee, or which were recommended by material suppliers for this particular application. It is also planned to test these materials, if possible, on sand-blasted and hand-cleaned steel panels, not only on this bridge but also at three other locations for comparative purposes.

As shown in Fig. 1, spans 4, 5, 6, 7 and 8 were selected for this experiment. Spans 1, 2, 3, 9, 10, 11 and 12, as well as intermediate sections on the test span, were painted with a three-coat system, consisting of a red lead—linseed oil primer and two coats of a black linseed oil topcoat.

The sequence of surface preparation, pretreatment, priming and topcoating for all of the test systems are listed in Table 1. Although commercial blast cleaning was employed on spans 4 and 5, it was necessary to carry out additional sandblasting on the 4 panels before metallizing. The top flanges had been Vacublasted, using G36 (Norton) grit, but immediately before metallizing they were reblasted, using half G36 and half G24. On panel A, girder 5 (south) only G36 was used, due to a shortage of the coarser material. A Metco gun type 4–E was used for both the $\frac{1}{8}$-in pure aluminum wire and the zinc wire.

The vinyl tapes were first applied in the shop, but had to be removed and reapplied in the field. During erection temporary ties were placed on the top flanges without the firm anchoring obtained on permanent ties, resulting in movement and abrasion which badly scuffed the tapes.

Weld Treatment Test

In previous work by the Council, over 40 methods of treatment have been investigated to improve the performance of paints over welds. The five methods found most effective in these earlier tests were, therefore, applied to the shop welds on the outer face of the south girder on span 4. Th horizontal welds at the top and bottom flanges were made with a continuous submerged arc weld, employing Lincoln Melt 840 and Lincoln Wire L–60. The vertical welds along the stiffeners were hand welded with an a–c machine, using a Lincoln Improved 47 electrode similar to E6013. Thus for each of the 5 treatments, 20 lin ft of submerged arc weld and 20 lin ft of hand-welded bead were treated. The treatment used consisted of plain water, chromic acid (5 percent acid diluted 3/1), phosphoric acid (10 percent acid diluted 3/1), MIL–C–10578A Type I (diluted 3/1) and a proprietary chromate—phosphate compound (diluted 2/1). It was noted that a white discoloration remained on the surface of the MIL–C–10578A after treatment was completed. In each case the solution was brushed onto the weld and onto an area 2 in on each side. It was then allowed to stand for 30 min before being

rinsed with plain tap water and dried with towels and an air blast. Shop priming with the control primer was carried out approximately 2 hr after drying. The layout of this test is illustrated in Fig. 2.

Future Plans

It is planned that these top flanges will be observed at least annually until a comparison is obtained among the various alternative systems. It is hoped that more than one system will be effective in order to give the railroads a choice on the basis of cost, application and local conditions. The information should also be of value in other applications and locations.

The weld treatment test, together with similar exposures elsewhere, will aid in the transfer of laboratory tests into practical application in the problem of painting over welds.

Acknowledgement

The test is the result of the planning and work of many people, including E. J. Ruble of the AAR, Committee 15 of the AREA, and the Research Committee of the SSPC, who contributed to the selection and planning phases. For the actual carrying out of the test work in the shop and field, credit is due to J. M. Peterson of the Chicago Great Western Railway and L. R. Morgan of the AAR, and in particular to the members of the Pittsburgh–Des Moines Steel Company, including Messrs. Hall, Perdue, Ryals, Van Pelt, Chapman, Bell, Stuchell, Barkley, Prewitt and Moore.

TABLE 1—PROTECTIVE SYSTEMS FOR TOP FLANGES

Rock River Bridge C–87–29, Byron, Ill.

	*Location**	*Surf. Prep.*	*1st Coat*	*2nd Coat*	*3rd Coat*
Metallizing					
Al-6mil—No sealer	4A	Blasted**	Pure ⅛" aluminum wire—	None	None
Al-6mil—With sealer	4B	Blasted**	Type 4E gun—(acetylene,	Black epoxy ester	None
Al-12mil—With sealer	4C	Blasted**	oxygen and air)	Black epoxy ester	None
Zn-12mil—With primer	4D	Blasted**	Zinc wire	2 component primer	None
Vinyl Tape					
10mil—unprimed****	5A	Blasted	None	10mil tape only	None
10mil—unprimed	5B	Blasted	None	10mil tape only	None
10mil epoxy primer	5E	Blasted	Epoxy ester-mixed pigment	10mil tape	None
20mil epoxy primer	5D	Blasted	Epoxy ester-mixed pigment	20mil tape	None
20mil unprimed	5C	Blasted	None	20mil tape only	None
10mil unprimed	7AB	W. brush	None	10mil tape only	None
10mil r.l. epoxy primer	7C	W. brush	Red lead epoxy ester	10mil tape	None
10mil oil base primer	7GH	W. brush	Red lead linseed oil paint	10mil tape	None
20mil oil base primer	7E	W. brush	Red lead linseed oil paint	20mil*** tape	None
20mil epoxy primer	7D	W. brush	Red lead epoxy ester	20mil*** tape	None
20mil unprimed	7F	W. brush	None	20mil*** tape only	None
Vinyl-Epoxy system	5KL	Blasted	Epoxy ester-mixed pigment	Vinyl with metallic flake	Vinyl with TiO_2, carbon
Vinyl-Epoxy system	7MN	W. brush	Epoxy ester-mixed pigment	Vinyl with metallic flake	Vinyl with TiO_2, carbon
Zinc dust paint	4KL	Blasted	Zinc dust paint	Same as 1st coat	None
Zinc dust paint	6KL	W. brush	Zinc dust paint	Same as 1st coat	None
Control system	5MN	Blasted	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	8M	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	1-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	2-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	3-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	9-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	10-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Control system	11-all	W. brush	Red lead-oil base	Black oil based paint (Field)	Black oil based paint (Field)
Coal tar mastic	4EF	Blasted	Cold applied mastic	Cold applied mastic (Field)	None
Coal tar system	71J	W. brush	Vinyl butyral wash primer	Coal tar and vinyl primer	Coal tar-vinyl enamel
Epoxy ester	5HIJ	Blasted	Red lead epoxy ester	Black epoxy ester	Black epoxy ester
Epoxy ester	6GH	W. brush	Red lead epoxy ester	Black epoxy ester	Black epoxy ester
Aluminum in petrol. deriv.	5FG	Blasted	Aluminum in petrol. deriv.	Aluminum in petrol. deriv.	None
Aluminum in petrol. deriv.	7KL	W. brush	Aluminum in petrol. deriv.	Aluminum in petrol. deriv.	None

TABLE 1 (Continued)

	*Location**	*Surf. Prep.*	*1st Coat*	*2nd Coat*	*3rd Coat*
Inorganic zinc silicate	4GH	Blasted	Mix 2 comps. Cold cure	----------	None
Inorganic zinc silicate	6IJ	W. brush	Mix 2 comps. Cold cure	----------	None
Chlorinated rubber	4IJ	Blasted	Red lead in chlor. rubber	Control sys., black oil-base (Field)	Control sys., black oil-base (Field)
Chlorinated rubber	6EF	W. brush	Red lead in chlor. rubber		
Linseed oil cementitious	4MN	Blasted	Cementitious pig. in LSO	Black cementitious oil paint (Field)	None
Linseed oil cementitious	6AB	W. brush	Cementitious pig. in LSO		
Neoprene system	6CD	W. brush	Neoprene-phenolic red lead	Black Neoprene paint	Black Neoprene paint (Field)
Lead silica chromate paint	6MN	W. brush	M50 in LSO and alkyd	Control sys., black oil-based (Field)	Control sys., black oil-based (Field)
Aluminum filler	8AB	W. brush	Aluminum rust prev. (heavy applic.) (Field)	None	None
Aluminum filler	8GH	W. brush	Control red lead oil paint	Aluminum rust prev. (Field)	None
Greasy rust preventive	8CD	W. brush	Rust preventive grease (heavy coat) (Field)	None	None
Greasy rust preventive	8EF	W. brush	Control red lead oil paint	Rust prev. grease (heavy) (Field)	None
Tie pads 8" x 16"****	8IJ	W. brush	Control system—3 coats (Field)		Asphalt-sealed fibrous pads (Filed)
Tie pads two 8" x 13"	8KL	W. brush	Control system—3 coats (Field)		Asphalt-sealed fibrous pads (Field)
Steel-pigmented putty	8N	W. brush	Mix 2 comps.—Trowell on (Field)	None	None

*See Fig. 1 for explanation of locations.
**Surface re-blasted (2 hr before metallizing), using 50/50 mixture of G36 and G24 grit in Vacublast.
***Two thicknesses of 10 mil tape.
****Brand No. 2.

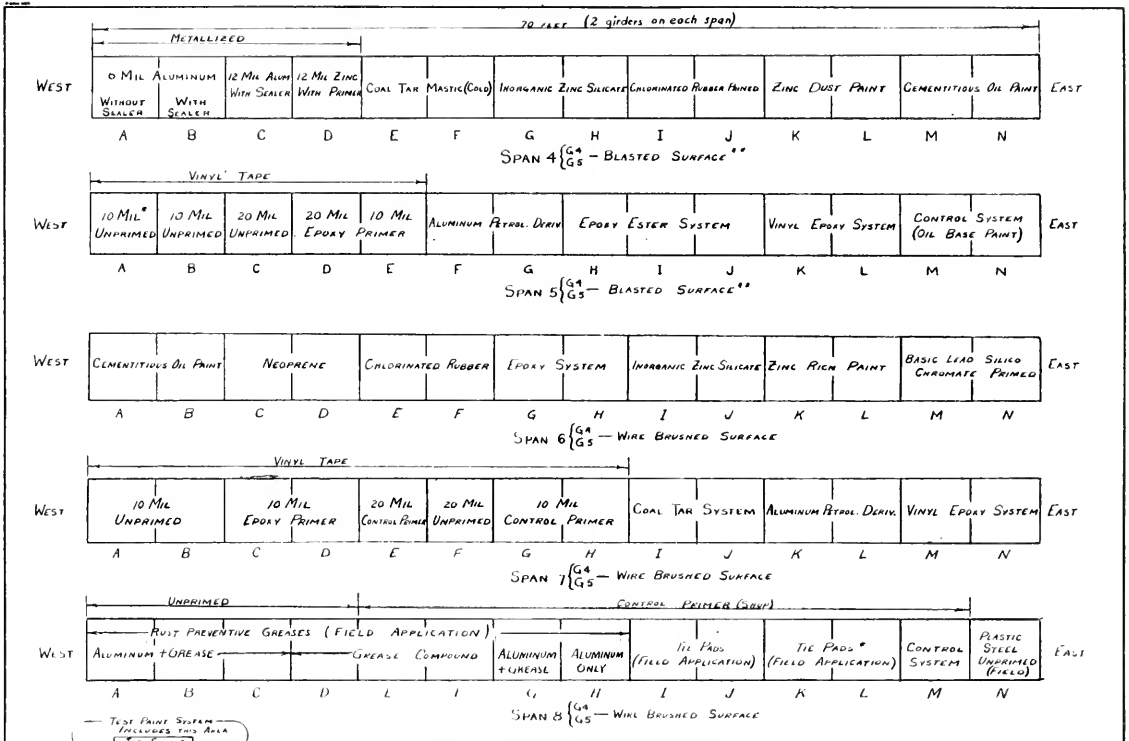


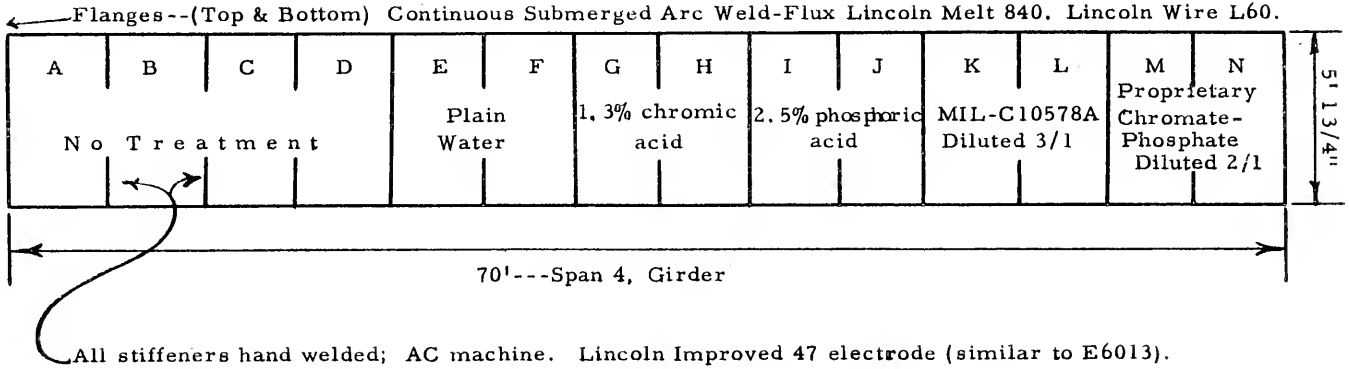
FIGURE 1. LOCATION OF PRINCIPAL TEST AREAS - TOP FLANGE PROTECTION ROCK RIVER BRIDGE C-89-29, BYRON, ILLINOIS

FABRICATED BY PAN-AMERICAN STEEL CO. FOR CHICAGO GREAT WESTERN RAILWAY, SEPT. 1954

EACH SPAN HAS TWO TOP FLANGES OF TWO GIRDERS G4 & G5

Figure 2.

Weld Treatment Tests



Report on Assignment 7

Bibliography and Technical Explanations of Various Requirements in AREA Specifications Relating to Iron and Steel Structures

E. K. Timby (chairman, subcommittee), P. E. Adams, Ethan Ball, J. E. Bernhardt, R. N. Brodie, James G. Clark, R. P. Davis, J. M. Hayes, B. G. Johnston, F. M. Masters, N. M. Newmark, G. E. Robinson, T. C. Shedd, J. E. South.

Your committee presents the following material as information, looking to its adoption and publication in the Manual next year as Appendix B of the Specifications for Steel Railway Bridges. Comments and criticisms are solicited.

APPENDIX B—TECHNICAL EXPLANATION OF VARIOUS REQUIREMENTS OF THE SPECIFICATIONS, AND BIBLIOGRAPHY

Explanations of Articles in Section A. Design and Manufacture

10. Depth Ratios
18. Live Load
19. Distribution of Live Load
20. Impact
24. Nosing
26. Bracing between Compression Members
28. Reversal of Stress
30. Secondary Stresses
31. Unit Stresses
35. Proportioning Web Members
40. Compression Members
41. Outstanding Legs of Angles
44. Net Section
47. Pitch and Gage of Rivets
49. Edge Distance of Rivets
54. Lacing
59. End Connection Angles
60. Proportioning Girders and Beams
61. Flange Section
65. Thickness of Web Plates
67. Intermediate Stiffeners
78. Shoes and Pedestals
79. Base and Masonry Plates

Explanations of Articles in Section C. High-Strength Structural Steel

1. Unit Stresses
2. Thickness of Material
4. Lacing
7. Secondary Stresses

Bibliography

Explanations of Articles in Section A. Design and Manufacture

10. Depth Ratios

The depth ratios specified were adopted many years ago and have resulted in structures that have proven satisfactory in railroad service. For these depth ratios the maximum deflections for open-deck bridges for the combined effect of E 72 live load and impact are approximately 1/800 of the span length for trusses and plate girders, and approximately 1/600 of the span length for rolled beams used as girders.

18. Live Load

The recommended live load, Cooper E 72 was adopted in 1935. This was discussed by Hardesty as follows: (1)*

* The numbers in parenthesis refer to references in the Bibliography.

"For railway bridges the normal live load, if made merely equal to that from the heaviest engines, presumably would be the Cooper E 70 or some equivalent loading. It was thought preferable to go slightly higher—to the Cooper E 72—in order to provide for the contingency of small increases in the near future. In making this choice of normal live load, it should be borne in mind that the impact formulas heretofore used probably are too high, and that some reduction has been made in the formulas adopted in Arts. 206 and 207 [current Art. 20]. It must not be forgotten that our experience relative to the carrying capacity of bridges is based mainly on structures rated in accordance with the impact formulas heretofore used, and that a reduction in impact will logically call for a live load assumption amply on the safe side."

The impact formulas in the current Specifications are given in Art. 20. These are based on tests made principally after 1935, and give impacts somewhat smaller for girder spans under 100 ft long and somewhat larger for truss spans, when compared with the 1935 formulas; the differences are not sufficiently large to alter the conclusions as to live load reached in 1935.

At this time steam locomotives have been largely replaced by lighter diesel locomotives, although there are still some steam locomotives in service which produce ratings in the range of E 72. There has been a tendency for diesel locomotives to increase in weight and this trend is expected to continue.

Reference is made to a Committee 15 report (2) which shows diagrams of diesel locomotives, and of heavy loads now being hauled by the railroads, and gives comparisons of their ratings with E 72. The report also gives cost data indicating that savings in construction costs by substantial reductions in design live load are quite small.

For members receiving load from more than one track, the proportions of full live load on the tracks to be used for design were determined by use of the theory of probability to determine the frequency with which stresses of various magnitudes might occur, consideration being given to the fact that most of the trains that pass over a bridge will produce lower stresses than the E 72 design live load on each track (3).

19. Distribution of Live Load

(a) In a bridge without stringers where a track is carried on transverse steel beams supported by longitudinal girders, the rails act as load-distributing beams resting on multiple elastic supports. A number of tests of such bridges in service under passage of locomotives have been carried out under the direction of Committee 30, which is continuing its work of theoretical analysis, the correlation of theory with the test results, and the development of a suitable formula for design. Until this work is completed, the empirical formula given in the specifications is to be used. It is considered to give safe design, based on comparison with test results. The values of k specified are suitable for open track or for track with minimum ballast and floor plates. Some reduction in the values might be made when a concrete slab is used instead of, or in addition to, a floor plate, or where the ballast exceeds 10 in. The amount of such reduction is now under study. (4) (5) (6)

(b) The loads for timber bridge ties can be determined analytically in the same manner as for the transverse steel beams referred to above. Such analyses show that the load on a tie will not exceed ⅓ of the axle load, and for tie supports in excess of about 8 ft the load will not exceed ¼ of the axle load. Tests have shown that the actual distribution of the wheel loads to the ties was quite irregular due to variations in modulus of elasticity, tie dimensions, and in play between rail base, tie plate, and

tie, as a result of which one tie may be obliged to carry well in excess of the load given above. However, design of a tie for ½ of the maximum axle load is considered adequate to avoid objectionably high stresses. (7)

(c) For a ballasted floor supported on longitudinal beams and girders, the requirements specified represent the judgment of Committee 15. Tests of two bridges having such floors showed the actual loads less than those specified. (6)

For open-deck bridges, the equal loading of the beams was considered proper on the basis that if it does not occur initially, it will occur if and when the stresses in the beams enter the plastic range.

20. Impact

The impact forces specified were based on investigations and tests of railroad bridges in service under passage of locomotive and train loads which have been in progress for many years. The early tests, prior to 1935, were made with mechanical instruments and included measurements of deflections and strains. In general, and particularly for shorter spans, the instruments were subject to considerable error due to vibration. The later tests were made with electrical instruments which permitted accurate measurements without disturbance from vibrations. Such work of testing is still in progress. While these later tests included many on beam and girder spans, only a few were made on truss spans, and work on such spans particularly is expected to continue for some years. The work is now being carried out jointly by Committee 30 and the research staff of the Association of American Railroads, the latter conducting the field and laboratory investigations. (9)

The magnitude of the rolling effect was determined from the early tests and confirmed by the later tests, which also showed that this was substantially the same for all speeds. (11)

The impact forces providing for direct vertical effects were adopted in 1948. For beam and girder spans, they were determined from the later tests. For truss spans, they were determined in part from the later tests and in part from the early tests. It was found that certain values obtained by the use of mechanical extensometers in the early tests were free from instrumental errors, thus justifying their use in the determination of impacts for longer truss spans, which had not been covered by the later test program. (8)

The later tests were made with electrical strain gages and oscillograms. A strain gage is connected to an oscillogram in such manner that the latter provides a continuous graphic record of the strains, or stresses, as a locomotive or train passes over the bridge. The ordinates on the resulting oscillograph represent the strains or stresses and the abscissae the elapsed time. (9) (10)

The use of a strain gage on each of two identically located points of, say, two girders of a girder span, each connected to its oscillogram, makes possible the determination separately of the several effects which together constitute the total impact at any instant during the passage of the locomotive or train. The difference between the mean stresses on the two graphs measures the rolling effect. The direct vertical effect is measured in two parts: (a) the speed effect is measured by the average of the mean stresses recorded on the two graphs; (b) the track effect for diesel locomotives, and similarly the combined track effect and hammer-blow effect for steam locomotives, is measured by the difference between the mean stress and the maximum or minimum stress on each graph. (10)

The final step in the determination of impact formulas from the tests consisted of the plotting of the test results on a chart and the selection of empirical formulas, verified by plotting on the chart, to fit these test results. (8) (9)

The requirements specified for impact for members receiving load from more than one track represent the judgment of the committee. For a double-track span, the shortest span for which the impact for only one track is to be used is 225 ft. For an open-deck through truss span of this length the use of impact for the second track would add approximately 5 percent to the total design load of the truss. It seems quite improbable that the full specification impact effects will occur simultaneously for both tracks, but even if this should be the case, the resulting increase in total load is small.

24. Nosing

Tests have shown that a reasonable load to provide for the nosing of locomotives can be taken as $\frac{1}{15}$ of the weight of one locomotive without tender. For the E 72 design live load, this results in a load of 20,000 lb as specified.

26. Bracing Between Compression Members

The requirements specified were adopted in 1935. Their basis is not known.

Winter (22) presents an analysis for determination of the strength and rigidity of such bracing required to prevent buckling of the compression members as this is affected by the crookedness and other imperfections which exist in compression members and by the deflections of the bracing panel points in the plane of the bracing. Such an analysis would require less capacity in the bracing than provided for by the specified 2½ percent shear. However, the bracing on railroad bridges is subjected to many other effects which are not provided for by a design for the other specified lateral forces. Some examples are dead- and live-load stress participation, unequal temperatures in the various members, and partial fixity of the bracing system by the fixed end shoes. In view of such effects and the importance of substantial bracing in railroad structures, the 2½ percent shear requirement is considered justified.

28. Reversal of Stress

The requirements specified are to provide against fatigue failure. They have been carried forward from the 1910 Specifications.

Tests have shown that the fatigue strength varies with the number of stress cycles and the range of stress in the cycle.

For a cycle in which the stresses are reversed, the fatigue strength is a minimum when the ratio of the two stresses of opposite sign is 1. As this ratio decreases, the fatigue strength increases, having closely a straight-line variation, with a fatigue strength 1.25 times the minimum for a ratio of 0.5, and 1.5 times for the limiting ratio of 0. (23)

Only limited data are available as to the number of cycles, and their stress ranges, which various members of a bridge might have to undergo during the life of a bridge. However, such data show clearly that the number of times when the stresses closely approach the design stress is quite small compared with the total number of stress applications. (24, p. 104) (25, p. 112)

To insure against fatigue failure of such members under the number of cycles and their stress ranges anticipated during the life of a bridge, it is indicated that the fatigue strength for a stress ratio of 1 can be taken as ⅔ of the yield point and for a ratio of 0 as equal to the yield point, with permissible unit stresses for the latter ratio equal to

those specified in Art. 31, and for other ratios proportional to the fatigue strengths. The specification requirements give results conforming closely to this.

For riveted connections, the fatigue strength is found to be less than for members, and it is indicated that the slip between the parts in riveted connections contributes largerly to this result. The specification requirement to proportion the connections for the sum of the maximum stresses will reduce, if not entirely eliminate, such slip, should avoid loosening of rivets as a result of slip, and should give adequate fatigue strength for the connections. (26)

30. Secondary Stresses

It is provided that if the secondary stress exceeds 4,000 psi for tension members and 3,000 psi for compression members, the excess shall be treated as a primary stress. The above stress of 4,000 psi for tension members when added to the maximum allowable stresses for all of the forces named in Art. 29 results in a maximum combined stress of $18{,}000 + 4{,}500 + 4{,}000 = 26{,}500$ psi, which is considered to be the maximum permissible. (1)

This Article also provides that secondary stresses due to truss distortion usually need not be considered in any member the width of which, measured parallel to the plane of distortion, is less than $\frac{1}{10}$ of its length. Excepted from this general provision should be the effects of secondary truss members, such as floorbeam hangers and subverticals; these may produce excessive secondary stresses in the chord unless adjustment is made in the lengths of the verticals.

31. Unit Stresses

(a) Structural and Rivet Steel

1. Axial compression, gross section

The formulas for compression members centrally loaded were adopted in 1935. (12). They were based on the theoretical analysis and studies of tests embodied in the reports of the Special Committee on Steel Column Research of the American Society of Civil Engineers, 1926, 1931, and 1933. Referring to the tests, it was found that the ultimate strength of columns could be calculated with a satisfactory degree of accuracy by the use of the theoretical formula, commonly known as the secant formula, basing ultimate strength on yield point of material. For columns forming part of a riveted truss, there are two elements of uncertainty, namely, the actual effective eccentricity of load which is dependent very largely upon the secondary bending stresses at the ends of the member, and the amount of initial curvature or crookedness. It was concluded that the ultimate strength could be fairly represented by a secant formula in which the eccentric ratio $\frac{ec}{r^2}$ is taken as 0.25 and the free length as $\frac{3}{4}$ of the center to center length of the member. For pin-connected members, study of pin friction led to the conclusion that the free length should be increased to about 0.85 of the center-to-center length. (0.875 was actually used).

The resulting secant formulas for riveted and pin ends are given in Appendix A of the Specifications. The use of factors of safety, about as for tension, as specified in Appendix A, gives allowable unit stresses.

As the secant formula is very inconvenient for general use, and as it was found that a parabola could be drawn to fit very closely the secant formula up to a slenderness ratio of 140–160, the simpler parabolic formulas shown in the Specifications were adopted for slenderness ratios up to 140.

2. Compression in extreme fibers of rolled shapes, girders, and built sections, subject to bending

The formula specified is based on the concept that the compression flange acts to some extent as a column, with deflections permitted normal to the plane of the web. It is especially adapted to design of rolled beams and girders having the compression flanges supported at intervals by laterals, cross frames, or knee braces.

The origin of the formula is not known, but it was probably derived from the parabolic formula specified for axial compression for members with riveted ends by multiplying it by the ratio 18,000/15,000 and assuming that r equals 0.245 b. This is a fair average value of r for compression flanges of beams and girders. If for any particular case the value of r varies materially from 0.245 b, the formula can be modified accordingly.

3. Bearing between rockers and rocker pins

The low bearing of 12,000 was adopted in order to reduce excessive wear of the pins, which was being experienced with previous higher bearing values.

4. Bearing on expansion rollers and rockers

The bearing values were adopted in 1935 and were based on static and rolling tests made on rollers and rockers. (13)

The average vertical pressures over calculated contact areas for loads substantially less than design values are in excess of the yield point, giving a flow of the material. It was concluded that the resulting "spread" of the roller and base, measured parallel to the axis of the roller at points near the surfaces in contact was the most satisfactory phenomenon to use in determining design values. Such "spreads" or deformations were measured in units of 0.001 inch per inch per 1000 strokes, each stroke corresponding to a roller movement of 4 in and an equal movement back. Design values according to the tests would give total deformations varying from about 3 units to less than 1.

35. Proportioning Web Members

In determining whether it is safe to keep an old structure in service, the "Rules for Rating Existing Iron and Steel Bridges", Part 7, this Chapter, govern. Experience with older structures, designed for lighter live loads, showed that in such structures the web members of trusses, particularly, reached their capacity sooner than other portions. This situation could be remedied either by providing an initial design of all members for an increased live load at higher unit stresses or by providing a truss design under which the web members reach their safe live load capacity at substantially the same increased live load as the remainder of the truss. The latter method was preferred by the Committee and is provided for by the Specification requirements. (1)

40. Compression Members

(a) Thickness of webs 1/32 and cover plates 1/40

These thicknesses are discussed by Hovey. (14) He develops the following formula for the minimum thickness of plate at which buckling of the plate will occur when the plate is simply supported at both edges and is stressed to the yield point in compression. In the formula, the coefficient 2.712 is 75 percent of the theoretical value, this reduction being made in order to provide for small initial buckles in the plate as rolled.

$$\frac{b}{t} = \sqrt{\frac{2.712\,E}{S_{cr}}}$$

where

b = the width of the plate
t = the thickness of the plate
E = Young's modulus = 29,000,000
S_{cr} = the yield point

For a yield point of 33,000, the ratio b/t equals 48.8. This shows that the provisions of the Specifications are very conservative, particularly for the webs of segments.

(b) Thickness when the stress is less than the allowable

In order to provide the same factor of safety against buckling that is provided for plates that are stressed up to the allowable, the formula clearly becomes:

$$\frac{b}{t} = \sqrt{\frac{2.712\,E}{S_{cr}\,f/p}} = \sqrt{\frac{2.712\,E}{S_{cr}}} \times \sqrt{\frac{p}{f}}$$

From this it follows that the ratios b/t for plates stressed up to the allowable may be multiplied by $\sqrt{p/f}$ when the stress is less than the allowable.

41. Outstanding Legs of Angles

Assuming elastic behavior up to the yield point, the following formula, derived from Bleich (20, p. 330 and 331), shows the width/thickness ratio at which buckling of the angle leg will occur when an equal-legged angle is stressed to the yield point:

$$\frac{b}{t} = \sqrt{\frac{0.384\,E}{S_{cr}}}$$

where

b = the width of the outstanding angle leg
t = the thickness of the angle
E = Young's modulus = 29,000,000
S_{cr} = the yield point

This gives values as follows:

Yield Point psi	$\frac{b}{t}$
33,000	18.4
50,000	14.9

For unequal-legged angles the values will be slightly higher.

To allow for imperfections that cause effective inelastic behavior below the yield point, conservative practice in the design of main members would permit about ⅔ of the foregoing values, or 12.3 and 10.0, for the tabulated yield points. These values are in line with the specification values of 12 and 10. For bracing and other secondary members, somewhat higher values are permissible. The ratios between the specification values of 14 and 12 and the formula values of 18.4 and 14.9 are, respectively, 0.76 and 0.81, and these ratios are considered satisfactory.

44. Net Section

This is discussed by Chapin. (15) He gives the history of this method of obtaining the net section of a riveted tension member to take account of the weakening effect of staggered rivet holes. He gives the rather complicated formula which represents the

theoretically correct solution of the problem, and states that the simplified formula shown in the Specifications gives approximately the same results. A chart for use with the formula is included with his discussion.

47. Pitch and Gage of Rivets

49. Edge Distance of Rivets

The provisions of paragraphs (b) and (c) of Art. 47 and for maximum edge distance in Art. 49 were adopted in 1943, and were based on the experience and judgment of the Committee.

The formulas for maximum pitch on a single line for sealing and for maximum edge distance, which is also for sealing, give smaller values than had previously been permitted. They indicate the belief that these values should increase with the thickness, though not in direct proportion, as this would give values either unnecessarily low for thin material or too high for thick material. It was further believed that staggered rivets on a second gage line reasonably close to the outer gage line, would also be effective in sealing. The maximum gage at which such a second line is considered effective was arbitrarily made the same as the maximum edge distance, which recognizes that this maximum gage should increase somewhat with the thickness.

The requirements for stitch rivets in compression members, that the maximum pitch in a single line shall not exceed $12t$ nor the gage $24t$, had been in force for many years and were considered satisfactory. However, when it was not practical to have a gage as large as $24t$, because the material was not wide enough, or not so disposed, as to permit it, the requirements often led to an extravagant number of rivets. The new provisions with respect to staggered pitch permit the use of a reasonable number of rivets in such cases. A study of the possible rivet patterns that might result from these provisions indicated that they would give greater security against buckling than the permissible pattern without stagger, using pitch of $12t$ and gage of $24t$.

54. Lacing

The probable maximum shears on column lacing were analyzed by Hardesty. (16) He lists the various causes producing shear on column lacing, as follows:

1. Transverse forces acting on the column.
2. Moments at the end of the column, or eccentric application of loads.
3. Initial curvature of the column.
4. The springing of the column as a result of Causes 2 and 3.
5. Local defects in the column, and initial stresses set up in the column during fabrication.

Causes 2, 3, and 4 are analyzed and are evaluated theoretically, by making certain assumptions which are consistent with those made in the formula adopted as the basis of column design. Formulas are developed for the shears and the results plotted on a diagram, together with the results of a number of tests. Finally the empirical formula shown in the Specifications was developed and plotted on the diagram. This design formula is such as to give values somewhat higher than shown by the analyses, in order to make some provision for Cause 5, which can not be evaluated theoretically.

The specification formula represents average conditions. For end conditions not properly covered by the assumptions made in the analyses, special investigation can be made by means of the appropriate formulas given. It is emphasized that this design

formula covers only shears due to accidental eccentricities and usual column imperfections, and does not include shears caused by transverse forces (Cause 1) or by known eccentricity of load.

59. End Connection Angles

The requirements for the connection angles for stringers were proposed by Wilson (21) after a study of the bending stresses in the angles as a result of the deflection of the stringers under live load and impact, and of the lengthening of the bottom chords of through truss spans under live load and impact. His conclusions follow.

The lengthening of the chords does not produce a very large flexural stress in the connection angles but does produce large flexural stresses in the floorbeams, both of which become smaller as the connection angles are made more flexible.

The deflections of the stringers under load produce a bending moment in the end connection, assumed to give maximum tension at the top varying to zero at the neutral axis, with the bottom of the connection in compression. The upper part of the connection is, therefore, the critical portion. It was found that at the top of the connection, the resulting deflection of the connection angles under maximum live load and impact was several times as great as the elastic deflection corresponding to a yield-point stress, even with connections more flexible than those commonly used previously. It is known that a deflection ten times as great as the elastic deflection produces a stress only slightly greater than the yield point, and also that structural steel can be stressed beyond the yield point several thousand times without failure. These facts, combined with the fact that the conditions of loading assumed for the analysis are of infrequent occurrence, were believed to explain why such connection angles have remained in service many years without failure. The excessive deflection of the angles also produces flexure in the rivets, particularly near the tops of the angles, and while failure of such rivets is not common, they have been reported on several bridges. Failures of connection angles at the top have also been reported.

For a given flexural stress, the deflection of the outstanding leg varies directly as the thickness of the angle, inversely as the square of the gage, and, very closely, also directly as the length of the stringer. The specified formula for the gage conforms to the requirements indicated by this statement, and will give connections more flexible than previously used. It is intended to represent a reasonable compromise between mathematical analysis and experience.

60. Proportioning Girders and Beams

This article provides for proportioning riveted members which take bending by the moment-of-inertia method, using a neutral axis along the center of gravity of the gross section and using the moment of inertia of the entire net section for determination of fiber stresses in tension and the moment of inertia of the entire gross section for determination of fiber stresses in compression. Actually, the neutral axis for a section through the rivet lines will not be along the neutral axis of the gross section but will be somewhat nearer the compression flange due to the rivet holes through the tension flange; if such a section is analyzed taking due account of the lack of symmetry of the section and consequent differences in distances from the neutral axis to the two flanges in determining the section moduli for the two flanges, it is found that the section moduli for the two flanges agree very closely with those prescribed for use in this Article. Accordingly, it is considered that the simple method prescribed will give flange stresses as close to the truth as can reasonably be determined.

61. Flange Section

The only requirements which need any comment deal with partial-length cover plates and the percentage of the total flange area permissible for cover plates, both of which were adopted in 1956.

Without extensions of cover plates beyond their theoretical ends, the critical stresses in fatigue failures of cover-plated beams and girders will occur at the ends of the cover plates, due to the abrupt changes in flange area. The limited data now available indicate that the extension of each cover plate far enough to develop its capacity beyond the theoretical end will reduce these critical stresses sufficiently to insure against fatigue failure under the number of cycles and their stress range anticipated during the life of a bridge. (24) (25)

In order to secure a compact flange section for heavy cover-plated beams and girders and to reduce the length and number of long rivets required to transmit flange stresses from the beam flanges and flange angles to the outer cover plates, it is desirable to limit the total area of the cover plates. The percentage specified is considered a reasonable maximum desirable for good design.

65. Thickness of Web Plates

The required thickness of web plate was discussed by Hovey. (14)

Bending moments in girder spans cause horizontal compressive stresses in the webs adjacent to the compression flanges. Vertical stiffeners are quite ineffective in supporting webs to resist buckling caused by such compressive stresses, and hence it is necessary either to provide horizontal stiffeners or to make the web of such thickness that stability against buckling is secured. Hovey develops the following formula to show the required ratio of clear depth of web to its thickness to give such stability against buckling:

$$\frac{h}{t} = \frac{25{,}000}{\sqrt{YP}}, \text{ when } YP = \text{yield point}$$

The compression flange secures the web against buckling where the web enters the flange, and it is assumed that this support will be adequate for at least 5 times the thickness of the web away from the flange. Hovey's study of a group of railway plate girders indicated that the unit fiber stress at a distance of 5 times the web-thickness away from the toes of the flange angles was about 0.65 times the maximum allowable extreme fiber stress in tension. The above equation then becomes:

$$\frac{h}{t} = \frac{25{,}000}{\sqrt{0.65\,YP}} = \frac{31{,}000}{\sqrt{YP}}$$

For a yield point of 33,000, this gives $\frac{t}{h} = 170.7$

This corresponds to the figure 170 given in the Specifications.

If p = the allowable extreme fiber stress
f = the actual extreme fiber stress, less than p
F = the factor of safety

Then the above equation can be written:

$$\frac{h}{t} = \frac{31{,}000}{\sqrt{Fp}} = \text{say } 170$$

If the fiber stress is f, then to maintain the same factor of safety:

$$\frac{h}{t} = \frac{31{,}000}{\sqrt{Ff}}$$

and clearly the ratio for the fiber stress f becomes $\sqrt{p/f}$ times 170, as given in the Specifications.

67. Intermediate Stiffeners

(a) Permissible depth of web without stiffeners

Hovey (14) has developed a formula for this depth:

$$\frac{h}{t} = \sqrt{\frac{4.83\,E}{fS}}$$

where

h = depth of web between flanges or side plates, inches
t = thickness of web, inches
E = Young's modulus = 29,000,000 psi
fS = shearing yield point, psi

For structural steel having tensional yield point of 33,000 psi, $fS = 21{,}000$ psi

Substitution in the equation gives $\frac{h}{t} = 81.7$.

The specification ratio is conservative and provides allowance for small waves in the surfaces of the plate.

(b) Stiffener spacing

The development of the specification formula is shown by Moisseiff & Lienhard. (19) It is based on a shearing yield point of 21,000 psi and a factor of safety of 1.5 against buckling of the web. It is explained that this value, while lower than used for tension and compression, is adequate because buckling of the web does not cause failure but only causes its proportionate share of compression to be transferred to the flange, and since this stress is small, it will cause only a correspondingly small overstress in the flange. Furthermore, the buckled web adjusts itself to sustain the shear by tension and transmit it to the vertical stiffeners.

The 72-in maximum spacing of stiffeners is specified in order to provide stiffeners at reasonably close intervals to aid in removing any small waves or buckles that may exist in the web as rolled.

(c) Size of stiffeners

The requirements for the size of stiffeners have been carried forward from older specifications. They appear in the 1910 Specifications and their origin is not known. The subject of proper stiffeners has been investigated by many and is discussed and analyzed in detail by Bleich, (20) who gives approximate formulas which can be used to determine the required moments of inertia of the stiffeners in order to properly stiffen the web. It is indicated that these give results which agree fairly well with laboratory tests but that further tests are necessary. The specification requirements will be compared with the requirements from his formulas.

Let

J = the required ratio of rigidity of stiffener to web plate

m = Poisson's ratio = 0.3
h = depth of web between flanges or side plates
d = required clear stiffener spacing
d_o = actual clear stiffener spacing
$B = h/d$
I = required moment of inertia of stiffener

Then from Bleich's formulas 772, 774, and 778, the following equation will develop:

$$I = \frac{d_o t^3 J}{12\ (1 - m^2)}$$

where

$$J = (28B^2 - 20)\left(\frac{0.971\ B^2 - 0.244}{B^2 - 0.109}\right)^3$$

or say

$$J = (28\ B^2 - 20)\ R$$

The expression is applicable only when h is equal to or greater than d.
Values of R follow:

B	R	B	R
1.0	0.543	1.6	0.766
1.1	0.605	1.7	0.781
1.2	0.652	1.8	0.797
1.3	0.691	1.9	0.807
1.4	0.719	2.0	0.818
1.5	0.746		

The table which follows shows the stiffeners which would be required by the specifications for a number of girders of extreme dimensions for each size of stiffener angle and each thickness of web plate and for maximum unit shear, and a comparison of their moments of inertia with those required by the above formula. As the specifications permit a maximum unit shear of 11,000, this value has been generally used in the table, except for Girder 5 where 10,000 has been used. It is believed that in actual railway girders the unit shear will never exceed 10,000; hence a deficiency in stiffener capacity as shown for Girder 4 will never occur. The conclusion can therefore be reached that the specification requirements will give adequate stiffeners for all railway girders, insofar as this can be determined from data now available.

No.	*Stiff. 2 Angles*	*Web*	*Flange Angles*	*Unit Shear*	h	d	B	d_o	*Stiff. I*	*Reqd. I*
1.	4x3 ½x⅜	60x⅜	6x6	11,000	48	37	1.30	37	18.9	3.4
2.	5x3 ½x⅜	90x½	6x6	11,000	78	50	1.56	50	36.7	20.7
3.	6x4x⅜	120x⅝	8x8	11,000	104	62	1.68	62	63.5	63.2
4.	7x4x7/16	144x¾	8x8	11,000	128	75	1.71	72	118.2	134.0
5.	7x4x7/16	144x¾	8x8	11,000	128	78.8	1.62	72	118.2	113.5
6.	7x4x7/16	150x¾	8x8	11,000	126	75.0	1.68	72	146.1	126.5
			and 12x½ side plates							

(d) Stiffeners on one side of the web

The Specifications do not specify the axis about which the moment of inertia of a single stiffener shall be calculated. Actually, a portion of the web will act with any such stiffener, and if an angle is used for the stiffener, the center of gravity of the

combined angle and web will be so close to the back of the angle that for all practical purposes the moment of inertia of the stiffener can be taken as for the angle alone about an axis through the back of the angle.

Referring to the table above, Girder 1 represents the maximum value of I which will be required for any stiffener for any girder 60 in or less in depth. The required I is 3.4. The I of one of the stiffener angles shown about its center of gravity axis is 4.2 and about the back of the angle axis is 8.1. This shows that for shallow girders the specification requirement is very conservative, as a single angle stiffener of the size specified for double-angle stiffeners is more than adequate.

78. Shoes and Pedestals

The requirements specified in the second paragraph are based on judgment and past practice. A consideration of relative deflections with those found in tests shows that these requirements will give stiff shoes and pedestals with substantially uniform pressure on the masonry.

79. Base and Masonry Plates

The specified relative thicknesses of base and masonry plates for rockers and for sliding bearings are based on the tests of rocker assemblies. (17) (18)

The rocker tests showed that the deflections of the base plate result in low pressures at the edges of the cantilevered plate and high pressures along the axis of the rocker except near the edges. The ratio of the high pressure to the average pressure on the base plate based on uniform distribution varies with the relative plate thickness, decreasing as this increases. For a plate thickness equal to ¾ the cantilevered length, the pressure varies but little from the uniform, and the ratio as shown by the tests was approximately 1.1. For a plate thickness equal to ½ the cantilevered length, it was slightly less than 1.5. For the specification requirements permitting an extension of the base plate beyond the end of the rocker equal to the thickness of the plate and a cantilevered length of the plate beyond the bearing line of the rocker equal to twice the thickness of the plate, the ratio should be approximately 1.5. This gives a pressure which it did not seem desirable to exceed but which the confined masonry can safely carry.

Explanations of Articles in Section C. High-Strength Structural Steel

1. Unit Stresses

(a) Axial compression, gross section, for compression members centrally loaded.

The parabolic formulas specified agree closely with the secant formulas referred to in the discussion of Art. 31 (a) 1 of Sec. A up to a slenderness ratio of 125.

(b) Compression in extreme fibers of rolled shapes, girders, and built sections, subject to bending.

The formulas specified were derived from the parabolic formulas specified for axial compression for members with riveted ends in the manner described in the discussion of Art. 31 (a) 2 of Sec. A.

2. Thickness of Material

As the modulus of elasticity of high-strength structural steel is the same as for carbon structural steel, and as the factor of safety against the yield point provided by the allowable unit stresses is for all practical purposes the same for both steels, the thicknesses specified in this Article can be determined by comparison with those specified

for carbon steel in Sec. A. All of these thicknesses vary with the square root of the ratios of the yield points.

$$\sqrt{\frac{50{,}000}{33{,}000}} = 1.23$$

From Art. 40, the minimum thickness ratio for webs of segments of compression members becomes

$$1.23 \times \frac{1}{32} = \frac{1}{26},\ \frac{1}{25} \text{ is specified}$$

From Art. 40, the minimum thickness ratio for cover plates or webs connecting the segments of compression members becomes

$$1.23 \times \frac{1}{40} = \frac{1}{32.5},\ \frac{1}{32} \text{ is specified}$$

From Art. 65, the minimum thickness ratio for webs of plate girders becomes

$$1.23 \times \frac{1}{170} = \frac{1}{138.5},\ \frac{1}{140} \text{ is specified}$$

From Art. 67, the minimum thickness ratio for webs of plate girders without stiffeners becomes

$$1.23 \times \frac{1}{60} = \frac{1}{48.7},\ \frac{1}{50} \text{ is specified}$$

The widths of outstanding legs of angles in compression were determined as described in the discussion of Art. 41, Sec. A.

The formula for stiffener spacing given in Art. 67 applies also to high-strength structural steel. However, due to the higher unit stresses used for web plates of high-strength structural steel, the sizes of the stiffeners required for deep girders will be greater. In the Explanation for Art. 67, Sec. A, a formula is given for determination of required moment of inertia of a stiffener. The table which follows shows the stiffeners which would be required by the Specifications for a number of girders of extreme dimensions for each size of stiffener angle and each thickness of web plate and for maximum unit shear, and a comparison of their moments of inertia with those required by this formula. It will be noted that for the deeper girders the specification stiffeners will be deficient unless the unit shear is reduced well below the allowable. It is doubted that the actual shears for such deep railway girders will ever exceed those for which the minimum stiffeners provided by the specification requirements will serve, but if so, the required stiffness can readily be determined by use of the data here given.

No.	*Stiff. 2 Angles*	*Web*	*Flange Angles*	*Unit Shear*	*h*	*d*	d_0	*Stiff. I*	*Reqd. I*
1	4x3 ½x⅜	60x⅜	6x6	16,000	48	31	31	18.9	5.3
2	5x3 ½x⅜	90x9/16	6x6	16,000	78	47	47	36.7	33.7
3	6x4x⅜	120x¾	8x8	16,000	104	62	62	63.5	109.0
4	6x4x⅜	120x¾	8x8	11,000	104	79	72	63.5	69.3
5	6x4x⅜	120x¾	8x8	10,000	104	75	72	63.5	54.5
6	7x4x7/16	144x⅞	12x½ Pls	16,000	120	72	72	146.1	197.5
7	7x4x7/16	144x⅞	"	14,000	120	77.5	72	146.1	157.0
8	7x4x7/16	144x⅞	"	13,000	120	80.5	72	146.1	138.0

4. Lacing

The requirements for lacing were determined in the manner outlined in the Explanation for Art. 54, Sec. A.

7. Secondary Stresses

The permissible secondary stresses of 5600 psi and 4200 psi are in line with those specified for carbon steel in Art. 30, Sec. A, when account is taken of the difference in yield points. See the Explanation for Art. 30, Sec. A.

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(3) Live Loads for Multiple-Track Bridges, H. C. Tammen, AREA Proceedings, Vol. 36, 1935, page 734.

(4) Beams on Multiple Elastic Supports, Part II, Modern Framed Structures, Johnson, Bryand & Turneaure.

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Report on Assignment 8

Specifications for Design of Corrugated Metal Culverts, Including Corrugated Metal Arches

W. B. Dowling (chairman, subcommittee), R. Archibald, H. F. Bober, R. N. Brodie, V. R. Cooledge, C. E. Ekberg, R. W. Gustafson, D. V. Messman, C. Neufeld, G. H. Perkins, A. G. Rankin, G. W. Salmon, L. L. Shirey, H. F. Smith.

Your committee presents as information the following revisions and additions to the specifications for corrugated structural plate pipe, looking to their adoption and publication in the Manual next year. Comments and criticisms are solicited.

These revisions and additions are intended to broaden the scope of the present specifications to include structural plate pipe-arches and arches and to bring other portions of the specifications in line with established industry and field practices.

Pages 1–4–25 to 1–4–32, incl.

SPECIFICATIONS FOR CORRUGATED STRUCTURAL PLATE PIPE

Page 1–4–25: Change title of specifications to read: "Specifications for Corrugated Structural Plate Pipe, Pipe-Arches, and Arches."

Revise Art. 1, Sec. A, to read "These specifications cover corrugated structural plate pipe, pipe-arch and arch culverts 60 in or more in diameter or in span."

Add the following paragraph to Art. 1, Sec. B:

Plates for a pipe-arch, when assembled, shall form a cross section made up of four circular arcs tangent to each other at their junctions and symmetrical about the vertical axis. The top section shall be an arc of not more than 180 deg nor less than 155 deg. The bottom section shall be an arc of not more than 50 deg nor less than 10 deg. The top and bottom sections are to be joined together by side sections, each having an arc of not less than 75 deg or more than 87½ deg and having a radius of from 15 to 22 in.

Pages 1–4–25 and 1–4–26: Revise Art. 3, Sec. B to read:

A coating of prime western spelter, or equal, of not less than 1½ oz per sq ft of each surface, shall be applied by the hot-dip process. If the average spelter coating as determined from the required samples is less than the amount specified above, or if

any one specimen shows a deficiency of 10 percent, the lot sampled shall be rejected. Spelter coating shall be of first-class commercial quality, free from injurious defects, such as blisters, flux and uncoated spots.

The sheets are to be galvanized after fabrication.

Page 1–4–26: In the first paragraph of Art. 6, Sec. B, revise item 5 to read "5. Identification symbols showing heat number."

Page 1–4–27: Add the following paragraph to Art. 1, Sec. C:

When specified, the structural plate for round pipe shall be formed so as to provide, when assembled, an elliptical cross section having a vertical elongation of approximately 5 percent. The use of elliptically shop-formed pipe is not a substitute for strutting, but will eliminate the need for heavy jacking.

Revise the title of Art. 1, Section D, to read "Maximum Gage of Plates for Structural Plate Pipes, Pipe-Arches and Arches (Cooper E 72 Live Load)."

In Table 1, under Art. 1, Sec. D, on the line of gages for 5 ft of cover, add the figure 8 under 132 in diameter pipe and the figure 7 under 144, 156, 168 and 180 in diameter pipe.

Page 1–4–28: Add a new Table 3 and a new Table 4 to Art. 1, Sec. D, as follows:

TABLE 3—STRUCTURAL PLATE PIPE-ARCH

Maximum Height of Cover in Feet	*Span of Pipe-Arch in Inches**								
	60	*72*	*84*	*96*	*108*	*120*	*132*	*144*	*156*
2–3	8	8	5	3	1				
4	10	10	8	5	3	1			
5	12	10	8	7	5	1			
6	12	10	10	7	5	3	1		
7	12	10	10	8	5	3	1		
8	12	10	10	8	7	5	3		
9	12	10	10	8	7	5	3	1	
10	12	10	10	8	7	5	3	1	
11	12	10	10	8	7	5	3	1	
12	12	10	10	8	7	5	3	1	1
13	12	10	10	8	7	5	3	1	1
14	12	10	10	8	7	5	3	3	1
15	12	10	10	8	7	5	3	3	1

* Pipe-Arches are available in a range of spans, rises and areas. Tabular values are for gage determination.

TABLE 4—STRUCTURAL PLATE ARCH

Maximum Height of Cover in Feet	*Span of Arch in Inches**									
	60	*72*	*84*	*96*	*108*	*120*	*132*	*144*	*156*	*168*
2	12	12	12	10	8	5	1			
3	12	12	12	10	8	5	3			
4	12	12	12	10	8	5	5	1		
5	12	12	12	10	8	7	5	3		
6	12	12	12	10	10	8	5	3	1	
7	12	12	12	12	10	8	5	3	1	
8	12	12	12	12	10	8	7	5	3	
9	12	12	12	12	10	8	7	5	3	
10	12	12	12	12	10	8	7	5	3	1

* Arches are available in a range of spans, rises and areas. Tabular values are for gage determination of arches having a rise to span ratio of 0.20 to 0.50, incl.

Revise Art. 2, Sec. D to read "For structural plate pipes and pipe-arches having a gage lighter than No. 1, the bottom plates may be specified of heavier gage than shown in the above gage tables."

Revise Art. 7, Sec. D to read:

The height of cover measured from base of rail to top of structural plate pipe shall be not less than half the diameter of the pipe, except that for pipes having diameters over 120 in, the minimum cover may be 5 ft.

The minimum height of cover measured from base of rail to top of structural plate pipe-arches and arches shall in no case be less than 2 ft and is restricted as shown on Tables 3 and 4.

Page 1–4–29: Add a new Art. 8 to Sec. D reading:

8. Maximum Height of Cover

The maximum height of cover as shown for Gage 1 material in Table 1 of Art. 1 of this section for Structural Plate Pipe, Strutted, may be increased 50 percent provided the number of bolts per foot of longitudinal seam is increased from 4 to 6.

Add "and Pipe-Arches" to the title of Art. 1, Sec. E.

Revise Art. 1, Sec. E to read "Where multiple lines of pipe or pipe-arch are erected, the adjacent sides shall be separated by one-half diameter or one-third the span to permit careful tamping of the filling material; however, the separation need not be more than 4 ft."

Page 1–4–29 and 1–4–30: Revise the title of Art. 3, Sec. E to read "Bedding and Backfilling—Pipe and Pipe-Arch Structures."

Revise the first paragraph of Art. 3, Sec. E to read "When a pipe or pipe-arch structure is to be erected in a trench, the width of the trench must be sufficient to permit thorough tamping of the earth backfill against every plate except the bottom 90-deg segment of pipe or the bottom arc of pipe-arch."

Add a new second paragraph to Art. 3, Sec. E reading "Rules given hereinbelow for bedding and backfilling pipe also apply to pipe-arches, except that rules involving pipe diameter are to be taken as applying to the vertical dimension of a pipe-arch.

In the existing second paragraph of Art. 3, Sec. E, revise the first sentence to read "The pipe shall be bedded in an earth foundation of uniform density".

Page 1–4–31: Delete the entire second paragraph of Art. 5, Sec. E.

Revise the existing third paragraph of Art. 5, Sec. E to read:

Where elliptically shaped pipe is to be field strutted, the length of the struts shall be such that they will fit snugly between the bearing blocks or sill without causing the elongated vertical diameter of the pipe to be extended. Where vertical diameter is to be elongated 3 percent by jacking, top and bottom sills extending from end to end of the pipe and compression caps of a softer wood than that of the struts, shall be used in conjunction with the struts.

Change the number of the table in Art. 5, Sec. E to 5.

Page 1–4–32: In the next to last paragraph in Art. 5, Sec. E, change the table reference to 5.

Revise Art. 1, Sec. F to read:

The footage to be paid for shall be the actual number of linear feet of the pipe, pipe-arch or arch. The number of linear feet shall be the average of the top and bottom center line lengths for pipe, the bottom center line length for pipe-arches and the average of the spring line lengths for arches.

Report on Assignment 10

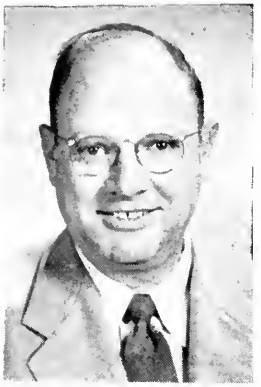
Specifications for the Design of Continuous Steel Railway Bridges

J. F. Marsh (chairman, subcommittee), H. A. Balke, R. T. Blewitt, J. G. Clark, T. L. Fuller, Shu t'ien Li, M. L. McCauley, J. C. Nichols, R. E. Peck, J. E. South.

Last year your committee presented Specifications for the Design of Continuous Steel Railway Bridges with the recommendation that they be adopted and published in the Manual. These specifications were approved by the convention and are now contained in the Manual. To the present time no criticisms have been received which would necessitate revisions in the adopted specifications.

The committee submits this final report as information with the request that the assignment be concluded.

Report of Committee 7—Wood Bridges and Trestles



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Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revised trestle plans, submitted for adoption and publication in the Manual ..... page 556

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.

   Progress report, submitted as information, with the recommendation that the material be published in the Manual a year hence ..... page 558

3. Specifications for design of wood bridges and trestles.

   No report. A progress report on the testing of ¼-scale Douglas fir stringers at the Forest Products Laboratory is being held up pending completion of entire investigation.

4. Methods of fireproofing wood bridges and trestles including fire-retardant paints, collaborating with Committees 6 and 17 and with the Fire Protection and Insurance Section, AAR.

   No report. Work on this assignment has continued during the past year looking to the presentation of a final report in 1960, which will include a specification for fire-retardant coatings. Work has already been started on an investigation of new fire-retardant additives.

5. Design of structural glued laminated wood bridges and trestles.

No report. The committee is developing recommended plans for glued laminated girders and trestle members, with accompanying tables, and will report on same to the Association as soon as possible.

6. Design of timber-concrete composite decks, collaborating with Committee 8.

Report submitted for adoption and publication in the Manual ..... page 562

7. Repeated loading of timber structures.

No report. Draft of a final report on this assignment is practically complete, and it is expected that, following review and approval by the committee, it can be presented in the June–July 1959 Bulletin.

8. Protection of pile cut-offs.

In the first phase of its study on this assignment, the committee is investigating various physical tests which may be conducted, but is not prepared to make a report at this time.

9. Hardening of timber bearing surfaces.

The committee is investigating previously developed information relating to this assignment, including work being done by the Forest Products Laboratory, but is not prepared to present a report.

10. Rules for rating existing wood bridges and trestles.

No report. During the past year the committee has started work on this assignment, looking to the eventual development of a method of rating existing timber bridges.

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
S. L. GOLDBERG, *Chairman*.

AREA Bulletin 548, January 1959.

Report on Assignment 1

Revision of Manual

Sidney L. Goldberg (chairman, subcommittee), C. E. Atwater, W. W. Boyer, B. E. Daniels, K. L. DeBlois, J. V. Johnston, C. V. Lund, W. B. Mackenzie, F. W. Madison, W. A. Oliver, O. C. Rabbitt, B. J. Shadrake, L. W. Watson, A. M. Westenhoff.

Last year your committee presented, as information, General Notes and Plans for Open-Deck Pile and Framed Trestles, Multiple-Story Trestles and Ballasted-Deck Pile and Framed Trestles (Proceedings, Vol. 59, 1958, pages 744 to 760, incl.)

Your committee now recommends that these General Notes and plans, with the minor corrections to some of them indicated below, be adopted and published in the Manual to replace obsolete drawings. Figs. 1 to 8, incl., presently shown on pages 7–4–3 to 7–4–10, incl., of the Manual.

Fig. 1—Floor Plan for Open-Deck Trestles.
In Note, change words "grade of lumber" to "species of lumber".

Fig. 2—Floor Plan for Ballasted-Deck Trestles.
Correct plan view to show every other stringer continuous over bents.

Fig. 3—Bulkheads and Miscellaneous Details.
In elevation showing Provision for Superelevation, designate top of low rail as such, and add vertical dimension "Distance as Required", between top of low rail and horizontal line for working points for center lines of piles.

Fig. 4—Cap Stringer Fastening and Pile Top Protection.
No change.

Fig. 5—Bent Details for Open-Deck Pile Trestle.
No change.

Fig. 6—Bent Details for Ballasted-Deck Pile Trestle
No change.

Fig. 7—Longitudinal Bracing.
Show bolts through cap into pile on Half Bent Elevation, vertical instead of sloping.

Fig. 8—Details of Footings for Framed Bents.
No change.

Fig. 9—Multiple-Story Trestle Bents.
No change.

Fig. 10—Multiple-Story Trestle Bents.
No change.

Fig. 11—Walk and Handrail—Open-Deck Trestles.
Change railing post size from 4"x6" to 4"x4". Change diagonal cuts on railing post braces to square ends.

Fig. 12—Water Barrel and Refuge Platform—Open-Deck Trestles.
Change railing post size from 4"x6" to 4"x4". Change diagonal cuts on railing post braces to square ends.

Fig. 13—Track Car Platforms—Open-Deck Trestles.
Change railing post size from 4"x6" to 4"x4". Change diagonal cuts on railing post braces to square ends. Extend 3"x6" runner from curb to running rail.

Fig. 14—Walk and Handrail—Ballasted-Deck Trestles.
No change.

Fig. 15—Water Barrel and Refuge Platform—Ballasted-Deck Trestles.
No change.

Fig. 16—Track Car Platform—Ballasted-Deck Trestles.
No change.

Report on Assignment 2

Grading Rules and Classification of Lumber For Railway Uses; Specifications For Structural Timber

Collaborating with Other Organizations Interested

R. E. Kuehner (chairman, subcommittee), W. L. Anderson, E. M. Cummings, K. L. DeBlois, W. C. Howe, V. T. Huckaby, R. P. A. Johnson, H. G. Kriegel, A. L. Leach, C. V. Lund, L. J. Markwardt, C. H. Newlin, Clifford Wendell, W. D. Keeney, T. K. May, W. H. O'Brien.

Your committee submits as information the accompanying table classifying stress-graded lumber as to the minimum quality recommended for railroad use for the various structures indicated. It is intended to be used as a guide by designers and purchasers.

Next year it is proposed to submit the table with the recommendation that it be adopted and published in Part 1, Chapter 7, of the Manual. Comments and criticisms are invited.

CLASSIFICATION OF STRESS-GRADED LUMBER FOR RAILWAY USES

Table 1—Minimum Quality Recommended for Uses Indicated

	KIND OF WOOD											
	SOUTHERN YELLOW PINE	LONGLEAF YELLOW PINE	DOUGLAS FIR (COAST REGION)	WEST COAST HEMLOCK	DOUGLAS FIR (INLAND REGION)	RED OAK WHITE OAK	BLACK GUM, RED GUM TUPELO	BEECH, BIRCH, ROCK ELM HARD MAPLE	EASTERN SPRUCE	SOUTHERN CYPRESS	TIDEWATER RED CYPRESS
RULES UNDER WHICH GRADED	SPIB	SPIB	WCLA	WCLA	WPA	NHLA	NHLA	NHLA	NLMA	NHLA	SCMA
BRIDGES AND TRESTLES											
Sills, Posts, and Caps	284	285	125b	225b	Pg. 134	317		315			
Bracing	333	333	123a	223a	Pg. 135	112	123	113			
Stringers	284	285	124b	224b		214		215			
Bridge Ties P & T Size	284	285	125b	225b		317		315			
Bridge Ties B & S Size	284	285	124b	224b		214		215			
Grard Timbers and Backwalls	284	285	Note A	Note A		214		215			
Planking (For Walks)	333	333	123a	223a	Pg. 133	112	123	113			
Planking (For Roadway Sub-Floor & Wear. Surface)	284	285	123b	223b	Pg. 137	117	123	118			
Railing	333	333	123a	223a	Pg. 135	112	123	113			
Railing Posts	333	333	Note B	Note B	Pg. 132	112	123	113			
BUILDINGS											
Sills and Sleepers	284	285	125b	225b	Pg. 134	317		315			
Posts and Caps	284	285	125b	225b	Pg. 134	317					
Beams	284	285	124b	224b		214		215			
Joists	227	229	123b	223b	Pg. 137						
Purlins, Rafters, Studs, Plates, etc.	227	229	123b	223b	Pg. 137				106		
Sub-Flooring (Plank)	284	285	123b	223b	Pg. 137	117	123	118			
Flooring (Heavy Duty)	284	285	123b	223b	Pg. 137	117	123	118			
CANOPIES AND SHEDS											
Posts, Sills, and Sleepers	284	285	125b	225b	Pg. 134	317		315			
Beams, Joists, Purlins and Rafters	284	285	123b	223b	Pg. 137						
CONCRETE FORMS											
Shoring and Plates	227		123c	223c					106		
Joists and Beam Forms	233		124c	224b					106		
Bracing	233		120c	220c					107		
Boards	196		Note F	Note F					87		

FOR NOTES SEE END OF TABLE

TABLE 1 (Cont'd)

	KIND OF WOOD											
	SOUTHERN YELLOW PINE	LONGLEAF YELLOW PINE	DOUGLAS FIR (COAST REGION)	WEST COAST HEMLOCK	DOUGLAS FIR (INLAND REGION)	RED OAK WHITE OAK	BLACK GUM, RED GUM TUPELO	BEECH, BIRCH, ROCK ELM HARD MAPLE	EASTERN SPRUCE	SOUTHERN CYPRESS	TIDEWATER RED CYPRESS
RULES UNDER WHICH GRADED	SPIB	SPIB	WCLA	WCLA	WPA	NHLA	NHLA	NHLA	NLMA	NHLA	SCMA
CULVERTS											
All Members	284	285	Note E	Note E							
PIERS AND WHARVES											
Sheet Piling	284	285	Note A	Note A	Pg. 137	117					
Crib Timbers	284	285	125b	225b	Pg. 134	317	319				
Sheeting for Ferry Racks and Transfer Bridge Fenders		-	125bb			313	319				
Caps (Supporting Tracks)	284	285	125b	225b	Pg. 134	317					
Stringers (Supporting Tracks)	284	285	124b	224b		214					
Rangers and Clamps (Supporting Tracks)	284	285	123b	223b	Pg. 137	117					
Fender and Fender Sheeting (For Piers)	284	285	125b	225b	Pg. 134	317	319	315			
Decking (Heavy Service)	284	285	123b	223b	Pg. 137	117	123	118			
Decking (Light Service)	284	285	123c	223c	Pg. 137	117	123	118	106		
Fender Pile Caps and Choking Timbers	284	285	125b	225b	Pg. 134	317					
Timber Below Water (Clamps, Bracing, Weles, etc.)	333	333	123c	223c	Pg. 137	117					
Timber Above Water (Not Supporting Tracks)	333	333	123b	223b	Pg. 137	117					
PLATFORMS											
Sills, Posts, and Caps	284	285	125b	225b	Pg. 134	317		315			
Beams	284	285	124b	224b							
Joists	227	229	123b	223b	Pg. 137						
Planks (Heavy Service)	284	285	123b	223b	Pg. 137	117	123	118			
Planks (Light Service)	284	285	123c	223c	Pg. 137	117	123	118	87		
TANKS AND SUPPORTS											
Posts	284	285	125b	225b	Pg. 134						
Bracing	333	333	Note C	Note C	Pg. 135						
Caps	284	285	124b	224b	Pg. 134						
Joists	227	229	123b	223b	Pg. 137						
Tank Bottom and Staves	349		Note D		Pg. 106						Pg. 25
Rafters	227	229	123b	223b	Pg. 137				106		

FOR NOTES SEE END OF TABLE

TABLE 1 (Cont'd)

	KIND OF WOOD										
	SOUTHERN YELLOW PINE	LONGLEAF YELLOW PINE	DOUGLAS FIR (COAST REGION)	WEST COAST HEMLOCK	DOUGLAS FIR (INLAND REGION)	RED OAK WHITE OAK	BLACK GUM, RED GUM TUPELO	BEECH, BIRCH, ROCK ELM, HARD MAPLE	EASTERN SPRUCE	SOUTHERN CYPRESS	TIDEWATER RED CYPRESS
RULES UNDER WHICH GRADED	SPIB	SPIB	WCLA	WCLA	WPA	NHLA	NHLA	NHLA	NLMA	NHLA	SCMA
TEMP. AND FALSEWORK											
Sills, Posts and Caps	284	285	125b	225b	Pg. 134	317				316	Pg. 59
Stringers	284	285	124b	224b						218	Pg. 56
Beams	284	285	124b	224b						218	Pg. 56
Joists	227	229	123b	223b	Pg. 137					121	Pg. 52
Lagging and Bracing	333	333	123a	223a	Pg. 135				107	114	Pg. 52
Wedges						109		107			
TRUSSES											
Upper and Lower Chords, Web Members	333	333	123a	223a							

	DOUGLAS FIR (COAST REGION)	WEST COAST HEMLOCK
NOTE A		
4" Thick or Less	Par. No. 123b	Par. No. 223b
6" Thick or More	Par. No. 124b	Par. No. 224b
NOTE B		
4" x 4"	Par. No. 122a	Par. No. 222a
4" x 6" and Wider	Par. No. 123a	Par. No. 223a
6" x 6" - 8" x 8" - 10", etc.	Par. No. 125a	Par. No. 225b
6" x 10" and Wider	Par. No. 124a	Par. No. 224b
8" x 12" and Wider	Par. No. 124a	Par. No. 224b
NOTE C		
4" x 4"	Par. No. 122a	Par. No. 222a
3" - 4" x 6" and Wider	Par. No. 123a	Par. No. 223a
NOTE D		
2" - 3"	Par. No. 167a	
4" and Thicker	Par. No. 167b	
NOTE E		
3" - 4" x 3" - 4"	Par. No. 122a	Par. No. 222a
5" - 8" x 5" - 8"	Par. No. 125b	Par. No. 225b
NOTE F		
Rough Concrete	Par. No. 120d	Par. No. 220d
Tight Boards	Par. No. 120a	Par. No. 220a

GENERAL NOTES

1. Numbers shown in the above table refer to paragraph (or page) numbers in the grading rules of the association shown opposite the various species.
2. The paragraph number, or lumber grade, shown for the structure member is the preferred minimum for railroad use and is to be taken as purely advisory. Where proper design indicates the use of a higher grade, selection should be made from Table 1 or Table 2, "Specifications for Structural Timbers".
3. All footnotes to Table 1, "Specifications for Structural Timbers", pertain to the above table.

Report on Assignment 6

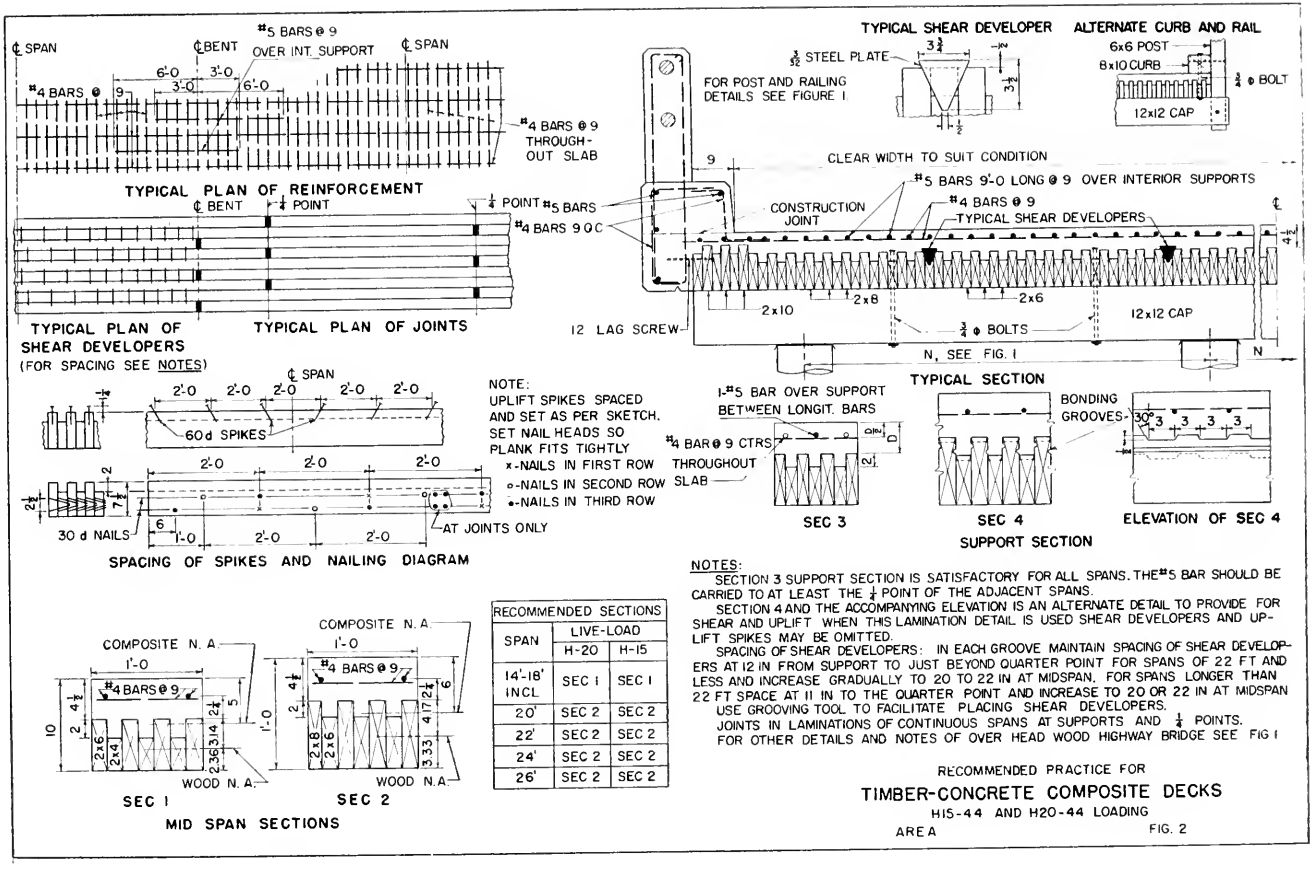
Design of Timber-Concrete Composite Decks

Collaborating with Committee 8

W. A. Oliver (chairman, subcommittee), C. E. Atwater, T. P. Burgess, E. M. Cummings, B. E. Daniels, W. A. Genereux, R. H. Gloss, G. J. Grantham, R. E. Grieder, J. F. Holmberg, W. D. Keeney, R. E. Kuehner, T. K. May, W. H. O'Brien, O. C. Rabbitt, D. V. Sartore, B. J. Shadrake, Josef Sorkin.

Your committee submits the accompanying drawing showing Recommended Practice for Timber—Concrete Composite Decks with the recommendation that it be adopted and published in the Manual as Fig. 2 under Recommended Practice for Overhead Wood Highway Bridge, page 7–M–4.

This drawing was presented last year as information (Vol. 59, 1958, page 796).



RECOMMENDED SECTIONS		
SPAN	LIVE-LOAD	
	H-20	H-15
14'-18' INCL	SEC 1	SEC 1
20'	SEC 2	SEC 2
22'	SEC 2	SEC 2
24'	SEC 2	SEC 2
26'	SEC 2	SEC 2

NOTES:

SECTION 3 SUPPORT SECTION IS SATISFACTORY FOR ALL SPANS. THE #5 BAR SHOULD BE CARRIED TO AT LEAST THE ¼ POINT OF THE ADJACENT SPANS.

SECTION 4 AND THE ACCOMPANYING ELEVATION IS AN ALTERNATE DETAIL TO PROVIDE FOR SHEAR AND UPLIFT WHEN THIS LAMINATION DETAIL IS USED SHEAR DEVELOPERS AND UPLIFT SPIKES MAY BE OMITTED.

SPACING OF SHEAR DEVELOPERS: IN EACH GROOVE MAINTAIN SPACING OF SHEAR DEVELOPERS AT 12 IN FROM SUPPORT TO JUST BEYOND QUARTER POINT FOR SPANS OF 22 FT AND LESS AND INCREASE GRADUALLY TO 20 TO 22 IN AT MIDSPAN. FOR SPANS LONGER THAN 22 FT SPACE AT 11 IN TO THE QUARTER POINT AND INCREASE TO 20 OR 22 IN AT MIDSPAN

USE GROOVING TOOL TO FACILITATE PLACING SHEAR DEVELOPERS.

JOINTS IN LAMINATIONS OF CONTINUOUS SPANS AT SUPPORTS AND ¼ POINTS.

FOR OTHER DETAILS AND NOTES OF OVER HEAD WOOD HIGHWAY BRIDGE SEE FIG 1

RECOMMENDED PRACTICE FOR

TIMBER-CONCRETE COMPOSITE DECKS

H15-44 AND H20-44 LOADING

AREA FIG. 2

Report of Committee 11—Engineering and Valuation Records

MORTON FRIEDMAN, *Chairman,*
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B. H. MOORE, *Secretary,*
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H. L. RESTALL
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J. E. STEIN
J. B. STYLES
J. R. TRAYLOR
E. L. VOGT
R. C. WATKINS
H. C. WERTENBERGER
W. C. WIETERS
J. L. WILLCOX
H. R. WILLIAMS
L. WOLF (E)
M. C. WOLF

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 566

2. Bibliography on subjects pertaining to engineering and valuation records
   Progress report, submitted as information ..... page 569

3. Office and drafting practices.
   Progress report, submitted as information ..... page 570

4. Use of statistics in railway engineering.
   Progress in study, but no report.

5. Construction reports and property records.
   Progress in study, but no report.

6. Valuation and depreciation:
   (a) Current developments in connection with regulatory bodies and courts.
   Progress report, submitted as information ..... page 571

(b) ICC valuation orders and reports.

No report.

(c) Development of depreciation data.

No report.

7. Revisions and interpretations of ICC accounting classifications.

Progress report, submitted as information ..... page 574

8. Simplification of records to determine original costs of tracks to be used in their retirements from the investment account.

Progress in study, but no report.

9. Simplification of annual reports on Form 588 to the Interstate Commerce Commission, and underlying completion reports.

Progress report, submitted as information ..... page 574

10. Photography in railroad construction and maintenance, collaborating with other interested committees.

Final report, submitted as information ..... page 592

THE COMMITTEE ON ENGINEERING AND VALUATION RECORDS,
MORTON FRIEDMAN, *Chairman.*

AREA Bulletin 548, January 1959.

Report on Assignment 1

Revision of Manual

W. A. Krauska (chairman, subcommittee), F. B. Baldwin, G. R. Berquist, P. D. Coons, E. M. Killough, W. M. Ludolph, F. A. Roberts, R. L. Samuell, J. N. Smeaton, E. W. Smith, H. R. Williams, M. C. Wolf.

The revision of Graphical Symbols, Figs. 2 and 3, appearing on pages 11–4–12 and 11–4–13 of the Manual, has been completed after an extensive study by a committee on the special assignment: "Standardization of Colors and Symbols to Be Shown on Maps", and the following recommendations with respect to these symbols are submitted for adoption:

GRAPHICAL SYMBOLS

Page 11–4–12, Fig. 2—Agriculture—Railways (Topographical Maps)—Railway Tracks (Track Maps): Reapprove with revisions (revised drawing presented herewith).

Page 11–4–13, Fig. 3—Profiles—Vertical Curves—Boundary and Survey Lines—Cartography: Reapprove with revisions (revised drawing presented herewith).

Your committee also recommends adoption of the following revisions to ASA references as shown on page 11–4–24:

Graphical Symbols for Plumbing: change (Z32.2.2–1949) to (Y32.4–1955).

Graphical Symbols for Heat-Power Apparatus: change (32.2.6–1950) to (Z32.2.6–1950, Reaffirmed 1956).

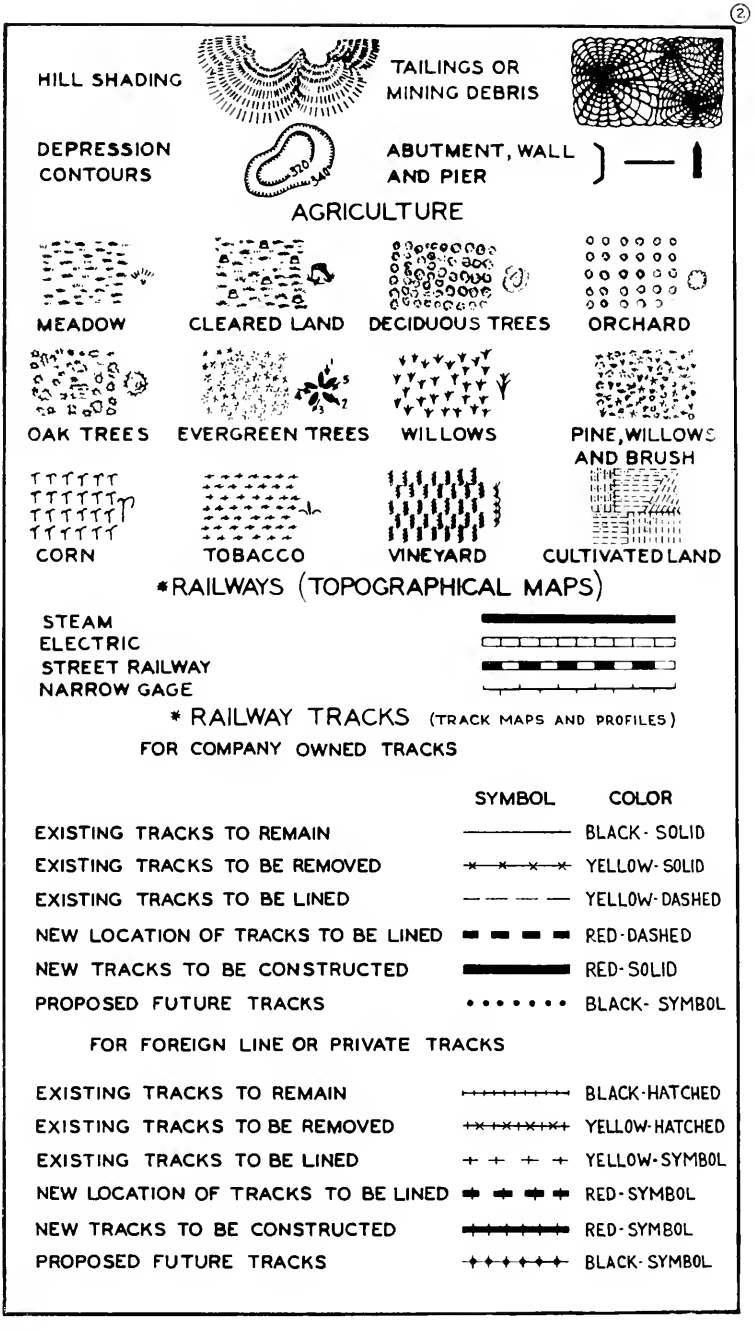
②
HILL SHADING
TAILINGS OR MINING DEBRIS
DEPRESSION CONTOURS
520
540
ABUTMENT, WALL AND PIER
AGRICULTURE
MEADOW
CLEARED LAND
DECIDUOUS TREES
ORCHARD
OAK TREES
EVERGREEN TREES
WILLOWS
PINE, WILLOWS AND BRUSH
CORN
TOBACCO
VINEYARD
CULTIVATED LAND
*RAILWAYS (TOPOGRAPHICAL MAPS)
STEAM
ELECTRIC
STREET RAILWAY
NARROW GAGE
* RAILWAY TRACKS (TRACK MAPS AND PROFILES)
FOR COMPANY OWNED TRACKS
SYMBOL
COLOR
EXISTING TRACKS TO REMAIN
BLACK - SOLID
EXISTING TRACKS TO BE REMOVED
YELLOW - SOLID
EXISTING TRACKS TO BE LINED
YELLOW - DASHED
NEW LOCATION OF TRACKS TO BE LINED
RED - DASHED
NEW TRACKS TO BE CONSTRUCTED
RED - SOLID
PROPOSED FUTURE TRACKS
BLACK - SYMBOL
FOR FOREIGN LINE OR PRIVATE TRACKS
EXISTING TRACKS TO REMAIN
BLACK - HATCHED
EXISTING TRACKS TO BE REMOVED
YELLOW - HATCHED
EXISTING TRACKS TO BE LINED
YELLOW - SYMBOL
NEW LOCATION OF TRACKS TO BE LINED
RED - SYMBOL
NEW TRACKS TO BE CONSTRUCTED
RED - SYMBOL
PROPOSED FUTURE TRACKS
BLACK - SYMBOL

Fig. 2.

PROFILES

ALINEMENT-4°CURVE TO RIGHT-2°LEFT — 4°C.R. 2°C.L.

ALINEMENT-2°CURVE LEFT-250'SPIRAL — 250'S. 2°C.L. 250'S.

VERTICAL CURVES — +0.1% +0.3% -0.2% -0.05% V.C.

* USE OF SYMBOLS IS RECOMMENDED FOR ALL TRACINGS OF EXHIBITS, CONTRACT MAPS OR CONSTRUCTION MAPS FOR NEW WORK WHEN A LARGE NUMBER OF PRINTS ARE REQUIRED. WHERE COLORS OR SYMBOLS ARE USED AN APPROPRIATE LEGEND SHOULD BE SHOWN.

BOUNDARY AND SURVEY LINES

FOREIGN R. OF W. LINE

STATE LINE

COUNTY LINE

TOWNSHIP LINE

CITY OR VILLAGE LINE

RESERVATION LINE

INNER PARCEL LINE

STREET BLOCK OR OTHER PROPERTY LINE

SURVEY LINE — RED

CENTER LINE — Track or Original Section Center Line. If Monumented, Show Location And Proper Symbol.

COMPANY PROPERTY R. OF W. LINE

CARTOGRAPHY

SECTION CORNER 17 16 20 21 SECTION CENTER 17

TRIANGULATION STATION OR TRANSIT POINT

BENCH MARK B.M.X1232 STONE MONUMENT

IRON MONUMENT CITY

VILLAGE CITY LIMITS

FIRE LIMITS CEMETERIES CEM.

CHURCH-SCHOOL COKE OVENS

TANKS AND OIL RESERVOIRS

OIL AND GAS WELLS MINE OR QUARRY M. or Q.

PROSPECT SHAFT

MINE TUNNEL LIGHTHOUSE OR BEACON

COAST GUARD STATION L.S.S. C.G.S.

MAGNETIC MERIDIAN N Variation Angle

★ HATCH OR COLOR (TRANSPARENT) RED

Fig. 3.

Report on Assignment 2

Bibliography on Subjects Pertaining to Engineering and Valuation Records

J. B. Byars (chairman, subcommittee), C. E. Clonts, C. E. Lex, Jr., B. H. Moore, F. H. Neely, E. J. Rockefeller, H. C. Wertenberger, W. C. Wieters, L. Wolf.

Your committee presents as information the following bibliography of subjects pertaining to railroad engineering and valuation records:

Depreciation

1. Depreciation Accounting. The Journal of Accountancy, June 1958, page 35. The case for the declining-balance method of depreciation as presenting a more accurate reflection of the economic usefulness of depreciable assets.

2. Price Level Depreciation Survey. The Journal of Accountancy, April 1958, page 36. A summary and analysis of opinions expressed by over 400 executives and educators on the desirability of disclosing current cost of depreciation.

3. Effect of Salvage Value on Depreciation. The Tax Magazine, February 1958, page 97. There is nothing startling in the new depreciation regulations with respect to salvage. However, they may require revision of some accounting practices with regard to salvage and possibly some adjustment of prior years income.

4. I.R.S. Restudies Depreciation Rules that Business Says are Obsolete. Business Week, February 16, 1957, page 89. The Internal Revenue Service has harkened to the charge by business that the depreciation period allowed on much property and equipment is unrealistic. I.R.S. is reviewing and overhauling Bulletin "F", the basic handbook for depreciation periods.

5. Sequel to an Engineering Viewpoint on Depreciation Accounting. Journal of Accountancy, 105: 35–40, June 1958. The author contends that declining balance and other methods of accelerated depreciation more accurately reflect the economic usefulness of depreciable assets than straight-line depreciation.

6. Original or Replacement Charge for Depreciation. Commerce and Finance, February 27, 1958, page 187.

7. Practical Method for Applying Current-Value Depreciation. National Accounting Association, Bulletin—January 1958, page 39.

Valuation

8. The Valuation of a Railroad in Reorganization. Columbia Law Review, March 1958, page 316.

9. Implications of Switching to Fair Value. Public Utilities Fortnightly, December 19, 1957. Reasons why it would be contrary to the investor's interest to shift over to fair value or current cost rate base practices.

10. Does Our Rate Making Process Need Overhauling? Public Utilities Fortnightly, May 8, 1958. Some ideas of modernizing regulatory procedures including specialized appellate tribunal.

11. Can Property Records Pay Their Way? Public Utilities Fortnightly, February 27, 1958. The answer is yes, but it is not easy.

Railroad Service

12. Discontinuance of Railroad Service. Public Utilities Fortnightly, May 8, 1958. An account of the problem which railroad companies face in seeking to control losses from unprofitable operations through discontinuance.

Automation

13. Answering Automations Biggest Question. Public Utilities Fortnightly, January 16, 1958. Whether persons dislocated by mechanization are able to find new jobs comparable with the ones displaced by automation.

Report on Assignment 3

Office and Drafting Practices

W. M. Ludolph (chairman, subcommittee), W. A. Krauska, A. T. Powell, H. B. Sampson, R. L. Samuell, H. A. Shinkle, J. R. Traylor, W. C. Wieters.

Your committee has from time to time reported on new materials, methods and processes to aid or improve office and drafting practices. This year, it comments on the permanency of the various kinds of records.

The useful life of records varies greatly with the amount of handling required; where they are stored; the material of which they are made; the sensitivity of the ink or coating material to light, temperature, humidity, atmospheric contamination, etc.; as well as a number of other conditions.

First, a few comments on the base material used for the records:

Tracing Cloth

Tracing cloth is probably the most permanent material for engineering maps and other records; however, it is subject to attack by some insects which will eat the sizing out of the cloth. It is also sensitive to high humidity at high temperatures. Usually, these problems are not present in well kept offices.

Life of Paper

The life of paper is unpredictable as it depends on the material from which it is manufactured and the manufacturing process.

Generally speaking, bond paper or a paper with a large rag content will be the most satisfactory for permanent records and records which require a large amount of handling.

Sulphite papers deteriorate quite rapidly but are usually used for records of a temporary nature on account of their economy.

All papers are affected by humidity. That is, if the humidity is too low, they will dry out and crumble, and if the humidity is too high, they are subject to fungus action. Humidity of 40 to 50 percent is recommended for most papers.

Also, paper is subject to deterioration by light, and if possible, records should be stored in the dark. Ordinary office lighting, however, does not seriously affect the life of paper.

Temperature is a large factor in the life of paper, and in order to secure the maximum life it should be kept in a cool place.

Plastic Films

Plastic films have come into use for office records and reproduction processes. However, these have not proved very satisfactory for the reason that they cannot be folded without damage and also because they become brittle with age. Work is in progress to produce a more satisfactory film.

Inks and Sensitized Coatings

1. Indian ink and printers ink are, for the most part, the most part, the most permanent, although they are subject to destruction by insects such as cockroaches, which can clean the India ink off of a fair-sized tracing over night or printers ink from a sheet of paper. This need be no problem, however, as many effective insecticides are on the market at the present time.

2. Dye inks vary greatly in length of life, but in most cases they outlast the paper on which they are used.

3. Graphite pencil records will outlast the paper, but are subject to smearing and smudging, unles a firm pencil is used. Colored crayons also produce almost permanent records.

4. The blueprint coating after being processed is very nearly permanent if placed on good paper and not exposed to strong light or to an alkaline atmosphere.

5. Dyes in the dye-process reproduction are sensitive to light, heat, atmospheric contamination and other conditions and, therefore, are not suitable for permanent records; however, under proper conditions, they will be satisfactory for a number of years.

6. Dyes used in dye transfer reproduction processes usually outlast the paper.

7. Thermal process coating records can be destroyed in a matter of minutes if exposed to heat, such as that of a radiator or of the bright sun in the summertime.

Report on Assignment 6

Valuation and Depreciation

(a) Current Developments in Connection with Regulatory Bodies and Courts

C. R. Dolan (chairman, subcommittee), R. B. Aldridge, S. H. Barnhart, G. R. Berquist, H. T. Bradley, J. B. Byars, C. E. Bynane, C. E. Clonts, P. D. Coons, S. Danby, R. S. Danis, V. H. Doyle, W. S. Gates, Jr., H. N. Halper, K. A. Heiny, J. W. Higgins, L. W. Howard, R. D. Igou, E. M. Killough, C. B. Martin, B. H. Moore, C. F. Olson, H. L. Restall, C. S. Robey, E. J. Rockefeller, J. B. Styles, E. L. Vogt, H. R. Williams, M. C. Wolf.

ICC Bureau of Accounts, Cost Finding and Valuation, Section of Valuation

The forces of the Bureau were engaged principally during the year in railroad and pipeline work, preparing tentative and final valuations on an annual basis for all pipeline companies subject to their jurisdiction. During the year statements were prepared showing the elements of value for all Class I line-haul carriers and switching and terminal companies as of December 31, 1956.

During 1957, Class I line-haul carriers charged Account 459, Valuation Expenses, $829,139 contrasted with $806,696 for 1956.

As of October 1, 1958, all pipeline and rail carriers were practically on a current basis in the filing of valuation reports with the Bureau, with the following exceptions: 5 line-haul carriers not filing for 1955 and 13 line-haul and 1 switching and terminal company for 1956. Valuation reports covering property changes for 1957 have been received from 26 rail carriers and 33 pipeline companies.

The backlog of valuation work (rail and pipeline carriers) in the Bureau as of October 1, 1958, was as follows:

	Annual Valuation Reports
Engineering Inventories	1,614
Land	866
Original Cost Summaries	27

The total number of personnel engaged in valuation work in the Section of Valuation on October 1, 1958, was 43, not including those field personnel which were previously merged with the staff of the Bureau's Accounting Examiners.

During the year the Commission issued the following orders covering valuation matters:

Order relieving all carriers from filing Forms B.V. 588–R "Report of Property Changes" in duplicate.

Order reversing the valuation regulations governing the reporting of property changes by pipeline carriers.

Order to carriers filing annual cost information for certain purchases of materials under Valuation Order 14 suspending the requirement.

The Bureau transferred all basic engineering field notes for all carriers to a federal records center. Carriers desiring to refer to any of these records should contact the Bureau ten days in advance of their proposed visit to Washington.

Elements of Value as of December 31, 1956—The Bureau of Accounts, Cost Finding and Valuation prepared its estimates for the Class I carriers covering the standard elements of value as of December 31, 1956, and released them February 25, 1958.

Elements of Value as of December 31, 1957—It is understood that the Bureau of Accounts, Cost Finding and Valuation, Interstate Commerce Commission, is preparing its estimates for the Class I carriers (line-haul and switching and terminal companies) covering the standard elements of value as of December 31, 1957, and that they will be released early in December 1958.

Report of the Committee on Valuation, National Association of Railroad and Utilities Commissioners

The above-named committee has recently issued its annual report for 1958, consisting of a text of 12 pages, with 2 appendices. Appendix A gives an index of cost for items in utility plants for the period 1940–1958, and Appendix B a list of the cases cited in the report. Copies may be secured from the Office of the Secretary, National Association of Railroad and Utilities Commissioners, Room 5310, Interstate Commerce Commission Building, 12th and Constitution Avenue, N. W., Washington 25, D. C., price 50 cents per copy.

The report in the main discusses the handling of "attrition" by the various state commissions. A questionnaire was sent to the state regulatory agencies requesting information as to the type of rate base utilized, whether attrition was considered and, if considered, the specific treatment given, and the reasoning or justification for the type of treatment.

After enumerating the replies received, the report concludes with the following summary:

"1. A generally acceptable definition of attrition as applied to the utility industry is as follows:

It is the decline in the percent earned on the rate base due to the replacement of plant items at price levels higher than those experienced when the original plant items were installed; it also comes about by additions to plant at a unit cost higher than the average cost of existing units.

"2. Attrition is a direct result of inflation or the decline in the 'real' value of the dollar.

"3. The majority of state regulatory agencies are cognizant of attrition as a factor in the rate-making process today.

"4. No single method of dealing with or providing for the attrition factor has been evolved. This is due in some degree to the different types of rate base utilized by various regulatory agencies.

"5. Those agencies adopting a fair value or reproduction cost new rate base feel that the rate base itself compensates for any erosion brought about by the attrition factor.

"6. The agencies adopting the net investment rate base or a variation thereof deal with attrition in one of three ways:

A. By an addition to the rate base to include a sum for extraordinary investment made by the utility; or

B. Through an adjustment upward to the rate of return authorized as reasonable by the agency in view of the existence of the attrition factor; or

C. Through the use of a year-end rate base where previously rates had been established on an average investment rate base.

"7. Attrition will remain a factor in the utility rate making process for the foreseeable future."

Revision of Depreciation Rates for Income Tax Purposes

In a previous report, the committee mentioned the efforts that were being made to modify or eliminate the 30-percent depreciation reserve that was imposed on the railroads as a condition to their changeover from retirement to depreciation accounting on road property for income tax purposes. Those efforts have finally resulted in the enactment of Section 99 of Public Law 85–866 (H. R. 8381) which was approved by the President on August 2, 1958. (Also known as Section 94 of the Technical Amendments Act of 1958).

The section provides that any taxpayer who changed from the retirement method of accounting for income tax deductions to the straight-line method of computing depreciation for any taxable year after December 31, 1940, and before Jannary 1, 1956, may elect to have it apply. Its application will have the effect of reducing the 30-percent depreciation reserve after adjustments for sudden obsolescence. The difference will be added back to basis for future recovery after December 31, 1955, based on the estimated remaining life of such property. This will result in larger deductions for depreciation for the years subsequent to December 31, 1955. While an election under this section precludes any refunds for the period 1942–1955, it permits the adjustment of the so-called "equity invested capital base" for the determination of excess profits tax liability for World War II and the Korean War profits. If applicable, this should increase the excess profits credit and decrease the income subject to the excess profits tax, resulting in refunds of the taxes paid during those periods.

The regulations under which the Internal Revenue Service will implement this section have not yet been published. It is probable that they will provide for a limited period during which the taxpayer may elect to accept the provisions of this section.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

M. M. Gerber (chairman, subcommittee), S. H. Barnhart, C. E. Clonts, C. R. Dolan, W. S. Gates, Jr., W. M. Hager, C. B. Martin, B. H. Moore, F. A. Roberts, C. S. Robey, H. B. Sampson, J. R. Traylor, J. L. Willcox.

This is a progress report, presented as information.

The Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission on April 23, 1958, amended Case A–101 relating to accounting for the cost of welding rail into longer lengths, and for retirement of track material not replaced.

This case formerly directed that when longer rails than those removed are applied in maintenance, the cost at current prices of the other track material removed, if more than the cost of such material applied, should be credited to Account 10, "Other Track Material"; if less it should be charged to that account. In either case the necessary adjustment should be included in Account 216 "Other Track Material."

This case now directs that the cost of welding rail into longer lengths shall be treated as part of the cost of the rail. The service value of rail joints and other track material retired and not replaced shall be charged to operating expenses.

Report on Assignment 9

Simplification of Annual Reports on Form 588 to the Interstate Commerce Commission, and Underlying Completion Reports

H. N. Halper (chairman, subcommittee), R. B. Aldridge, J. L. Becker, H. C. Boley, S. Danby, C. R. Dolan, V. H. Doyle, M. Friedman, M. M. Gerber, W. M. Hager, N. Hammond, J. W. Higgins, W. H. Kiehl, B. F. Nauert, C. F. Olson, H. L. Restall, E. L. Vogt, R. C. Watkins, H. R. Williams, M. C. Wolf.

Part 1—Simplification of Completion Reports

The completion report has now become familiar to practically all railroad engineers. It is essentially an engineer's report showing the details of units, quantities and costs of construction projects. Although it was originally prescribed by a mandatory order of the Interstate Commerce Commission, it has now become an essential corporate record used for many purposes, particularly in connection with property control records, depreciation, income tax benefit reports, retirements, insurance, corporate financing, etc.

To simplify it so that on the one hand it would consume the least time possible of competent engineers and at the same time to preserve its essential details desired and required for corporate purposes is, indeed, a formidable task.

Members of the committee were assigned particular groups of properties contained within various investment primary accounts and have given it careful study with reference to the units and quantities which are now being reported, suggesting modifications for simplifying them.

The simplifications were then taken up at a meeting of the entire committee; and after deliberation, the committee makes the following observations and recommendations:

A. Mass Property: Within this classification are grouped the accounts which con-

tain predominantly mass property, although they do contain certain large units. These are Accounts 2½, 3, 5, 8 to 12, both inclusive, 13, 31, and 39.

B. Machinery and Equipment Property: Accounts 37, 38, 44, 45, and 51 to 58, both inclusive.

C. Structural Property: Within this group are included those accounts which contain structures primarily, although some of them contain also, to some extent, mass property. These accounts are 6, 7, 16 to 24, both inclusive, 29 and 35.

D. Communication Systems; and Signals and Interlockers: Accounts 26 and 27 containing both structural and mass properties.

With reference to Classifications A and B, that is, Mass Property and Machinery and Equipment Property, the committee found that the present requirements as shown in the Revised Supplement No. 4 to Valuation Order No. 3, Second Revised Issue, effective January 1, 1933, "List of Units for Use of Carriers in the Preparation of Completion Reports and the Record of Property Changes" as prescribed by the ICC, are satisfactory. Most of them are not burdensome, others cannot be further simplified without destroying the essential requirements of a property record.

With reference to Account 26—Communication Systems, and Account 27—Signals and Interlockers, and particularly its mass property, the committee recommends continuation and expansion of the practice of combining similar and related items into types and adjustment units.

With reference to structural property, the committee presents simplifications in reporting as detailed below and in the accompanying tables. These tables give samples of reporting Account 16—Station and Office Buildings, and Account 17—Roadway Buildings, showing in parallel columns the present and proposed reporting.

The committee recommends that full details of construction and costs be preserved permanently in the so-called "project envelope" even though the recommended simplified list of units be used in the completion report; also, that record construction plans which are an essential part of the completion report be permanently preserved.

The committee is fully cognizant of the fact that for corporate purposes it may be necessary to record more detailed units and data than those presented above. It therefore cautions that the list of units be considered a "minimum requirement" and that it be expanded and supplemented at the discretion of each carrier.

Structural Property

Structural property, presented herewith for simplified reporting, covers all buildings and structures, including pipe lines, machinery, other than shops and power plant machinery chargeable to Accounts 44 and 45, and all other items normally found in the following accounts:

Account 16—Station and Office Buildings
17—Roadway Buildings
18—Water Stations
19—Fuel Stations
20—Shops and Enginehouses
21—Grain Elevators
22—Storage Warehouses
23—Wharves and Docks
24—Coal and Ore Wharves
29—Power Plants
35—Miscellaneous Structures

The units and method of reporting physical property, including structural, in completion reports is prescribed by the Interstate Commerce Commission in detail, in revised List of Units, Supplement No. 4 of Valuation Order No. 3, second revised issue effective January 1, 1933. The list provides for all structural items to be shown in such detail and in terms that reproduction prices as of any given date can be applied to the quantities so reported to determine the reproduction cost new in place of any building or structure or of any component parts thereof.

On account of the detail required, in many instances a field inventory of each new building or structure has to be made by engineers or inspectors to obtain the reproduction units in the terms needed for completion reports, for these units as a rule are quite different from those charged out to the job on store department requisitions and as reported used in the structure by foremen in job reports from which the costs of structural property are developed.

It is believed that the list of units recommended below will conform with present-day needs and requirements of the commission and be useful as well for corporate purposes, such as valuation, accounting, depreciation, etc.

The committee again strongly recommends that full details of construction and costs of the various component parts of structural units of property which are frequently required for estimating, retirements and other corporate purposes be preserved permanently in the "project envelope" even though the recommended simplified list of units are used in the completion reports; also, that record construction plans which are an essential part of the completion report be permanently preserved. The committee considers the recommended list of units as a "minimum requirement." It is left to the discretion of each carrier to expand it whenever it deems it desirable for corporate or other purposes.

Account 16—Station and Office Buildings

Structures should be reported individually and definitely located by towns, survey stations, mile posts or other references.

Each building or structure, including attached platforms, should be described in detail, stating size, type of consrtuction, kind of foundation and roof, mentioning any other important features or characteristics and giving reference to engineers' or "architects' special or standard plans ..... Each

For large and important buildings additional detail should be shown, as follows:

1. Plumbing	(General	description)		Lot
2. Heating	("	"	)	"
Unit heaters	("	"	)	Each
3. Lighting	("	"	)	Lot
4. Elevators and conveyors	("	"	)	"
5. Air conditioning system	("	"	)	"
6. Loud speaker system	("	"	)	"
7. Machinery and equipment	("	"	)	"
8. Power lines (inside)	("	"	)	"
9. Fire protection	("	"	)	"
10. Sundry items (other minor items not mentioned individually above)	("	"	)	"
11. Any other important additional items	("	"	)	"

Furniture and fixtures in all buildings should be briefly described and shown as a separate group subdivided as follows:

Furniture and fixtures (other than office equipment) ..... Lot
Office equipment—number of units ..... "

When the unit "lot" is used, the cost should always be given the same as for individual buildings or structures.

Representative reporting for other items of property in this account is as follows:

Tractors and trucks (Brief description) ..... Each
Stock pens (Size or capacity and type of construction) ..... "
Scales complete (Kind, make, model, size, capacity and kind and size of pit and scale house) ..... "
Platforms, high wood (Complete description showing size and kind of foundation) "
Platforms, low brick (Size or sq ft, kind and Lin Ft of curbing) ..... Lot
Platforms, other (Kind, thickness, size or sq ft and kind, size and Lin Ft of curbing) ..... "
Fences (Kind and type of construction) ..... Lin Ft
Wells including casing (Diameter and depth) ..... Each
Water tank (Size, kind and type of support) ..... "
Outside lighting (Number of lights and brief description) ..... Lot
Outside pipe lines (Kind and size of pipe, indicating whether underground or elevated and description of supports and conduits when applicable) ..... Lin Ft
Mail cranes (Trade name and kind) ..... Each
Freight derricks and cranes (Kind or make and capacity) ..... "
Windmills (Kind, make, diameter of wheel and kind and height of tower) ..... "
Landscaping (Brief description) ..... Lot
Manholes—complete ..... Each
Cesspools—complete ..... "
Inside changes and rearrangements in existing structures not affecting type of structure (General description) ..... Lot

For additional items in this account, such as grading, drainage, protection work, and paving, see Accounts 3, 6, and 39.

Additions to existing structures should be shown in the same detail as new structures.

Account 17—Roadway Buildings

Buildings and appurtenances (see Account 16).
Machinery (see Account 44).

Section houses and other buildings of like size and importance should be reported in the same detail as "large and important buildings" in Account 16.

Account 18—Water Stations

Buildings and appurtenances (see Account 16).
Water tanks (State whether fresh water or treating tank with complete description of tank, including frost box; stating size, kind of construction, and supports showing total weight of steel in the tank including steel supports and treating column when applicable) ..... Each
Water columns and diesel locomotive hydrants (Kind, size and description of pit) Each
Pipe lines (Kind and size of pipe, stating whether underground or overhead and description of supports, insulation and conduits when applicable) (cast iron pipe-net ton; other pipe ..... Lin Ft
Dams, reservoirs and settling basins (see Accounts 3 and 6).
Drilled wells (size and depth including casing) ..... Each
Dug wells and cisterns (Give size and kind of walls) ..... "
Pumping machinery—boilers including fitting (Type and hp) ..... "
compressors (kind, make, and size) ..... "
pumps including pump jack (kind, make and capacity) .... "
engines (kind, make, size, and hp) ..... "
motors including switch board rheostat and connections (type and rpm) ..... "
Water treating plant—brief description, maker and capacity ..... "

Account 19—Fuel Stations

Buildings and appurtenances (see Account 16).
Service tanks, pipe lines and equipment (see Account 18)
Fuel oil station:

Oil storage tanks (kind, size or capacity, type roof, and weight of steel)	Each
Dike around tank (see Account 3)	
Oil cranes or diesel fuel oil hydrants (kind and size)	Each
Oil troughs (description, kind and size)	"
Oil sumps (kind and size)	"
Servatrain unit (brief description)	"
Oil unloading station or tower (brief description and size)	"
Equipment in fuel oil pump house:	
Miscellaneous mechanical equipment (brief description)	Lot
Fire protection:	
Equipment in pump house: pump (kind, make and capacity)	Each
Foamite tank, including fittings (kind, size and capacity)	"
Foamite fire protection equipment including pipe lines (brief description)	Lot
Coaling station (state type, trade name and model, storage and operating capacity in tons, kind of elevators and conveyors, number of aprons and tracks served. Give kind, description and capacity of sanding facilities, if any, and reference to plans)	Each

Account 20—Shops and Enginehouses

Buildings and appurtenances (see Account 16).

Diesel shop (describe in detail stating size, type of construction, kind of foundation and roof and any other important features, giving reference to standard or special plans)		Each
1. Plumbing	(Brief description)	Lot
2. Heating	(" ")	"
3. Lighting	(" ")	"
4. Power wiring	(" ")	"
5. Inside piping	(" ")	"
6. Furniture and fixtures	(" ")	"
Turntables and transfer tables:		
1. Pit (Size and kind)		Each
2. Table (Type and size)		Lb
3. Table tractor (Kind, make, hp)		Each
Cinder pits (Size and type construction)		"
Smoke stacks (Size and type construction)		"
Lorry and wheel tracks (Description)		Lin Ft
Platforms (see Account 16)		
Sanding plants (Complete description, capacity and plan reference)		Each
Inside pipe (Size and kind, designating the building)		Lin Ft
Driveways (Kind, thickness of base and wearing surface)		Sq Ft
Car repair sheds (Description, size and type construction)		Each
Wells and cisterns (see Account 18)		"
Pipe lines (see Account 16—outside pipe lines)		Lin Ft
Car washing machines—description		Each
Engine washing machines—description		"
Oil unloading station—see Account 19 (Unloading towers)		"

Account 21—Grain Elevators

Buildings—in same detail as Accounts 16 and 20
Machinery—complete description

Account 22—Storage Warehouses

See Accounts 16 and 20.

(Text continued on page 587)

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions							
Passenger depot, one story, brick and Colorado red stone, solid 12" and 16" thick; concrete basement; floor, concrete, Terrazo and composition tile; ceiling plastered on metal lath acoustal tile and sheet rock; interior finish plastered face brick, stone and glazed tile, wood panel; openings, doors and windows, steel lintels and cast lender stone trim on windows; partitions Pryobar brick; roof, insulated built up tar and gravel, roof overhang 4' - 10' supported by joists; downspouts, galvanized steel pipe.				Passenger depot 45' x 136', one story brick, stone and concrete with concrete basement, insulated built up tar and gravel roof, 5' x 20' and 7' x 23' canopies and galvanized iron downspouts.			
Building 45' x 136' x 12'	Cu. Ft.	73,440	$ 97,545.20	Plan CEOA No. - - - -	Each	1	$105,531.85
Foundation							
Excavation, common	Cu. Yd.	666)					
Concrete, reinforced	"	138)	3,036.65				
Reinforcing steel	Lb.	11,619)					
Canopies							
Channel iron and wood joists supports tar and gravel roof 5' x 20'	Sq. Ft.	100)	Included in Cost of Building				
Channel iron I-Beams and wood joists supports tar and gravel roof 7' x 23'	"	161)					
3/4" rods from roof overhang and wood joists supports tar and gravel roof 2 - 2'10" x 21'6"	"	61)					
Plumbing							
Water closet, Kroehler No. K-4291-ET vit. china	Fixture	8)		Plumbing equipment	Lot	1	9,571.45
Urinal, Kroehler No. K-4982-T Wall vit. china	"	3)					
Lavatory, Kroehler 19" x 17" No. K-1300 vit. china	"	7)					
Sink 18" x 22" Kroehler No. K-5200	"	1)					
Drinking fountain, Kroehler No. K-5340-A Rockbrook	"	1)	9,571.45				
Drinking fountain, Halsey-Taylors S-C 10-A electric operated	"	1)					
Sump pump, Brown-Brockmeyer Co. Dyna-Line ½ HP type RL	"	1)					
Hot water heater Red Arrow Model RA 40 N 1 cap. 40 gallons	"	1)					
Heating							
Hot air gas fire furnace Bryant Model 450 A 87 (Heat dispersed and returned to furnace through sonoduct tubing) BTU input 450,000 BTU output 360,000	Each	1)	6,258.27	Heating system, hot air gas furnace	Lot	1	6,258.27
Hot air overhead gas fired unit heater Bryant Model 125-32 BTU input 125,000 BTU output 100,000	"	1)					

ACCOUNT 16 - STATION AND OFFICE BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions (continued)							
Air Conditioner							
Chrysler Air-Temp Compressor unit 15 ton 1315 and water cooling tower	Each	1	$ 4,238.43	Air conditioning system	Lot	1	4,238.43
Lighting							
Wiring in conduit	Outlet	144)		Electric lights and fixtures	Lot	1	12,122.54
Fixtures:		)					
Incandescent Quad No. 8145-V	Each	5)					
" Art metal No. 478	"	44)					
" " " No. 457	"	27)	12,122.54				
" Kayline Cat. No. Y-6206	"	7)					
Fluorescent Silveray Cat. No. 160	"	16)					
" All Bright Cat. No. CR-402	"	10)					
" Gotham Strip Cat. No. 21544-1 four light	"	9)					
Pull chain, Quad incandescent	"	1)					
Furniture							
Clock, electric, surface mounted numerals, recessed works #1944, Shelton Edwards & Co.	"	1	125.22	Electric clock - Shelton Edwards & Co.	Each	1	125.22
Sundry Items							
Sign - "Santa Fe" neon tubes-blue translucent plastic face letters stainless steel sides	"	1)		Signs inside and outside depot	Lot	1	6,013.50
Sign - "Lubbock" porcelain enameled blue vitreous steel face letters and stainless steel sides incandescent lamps back of each letter	"	2)					
Sign - "Traffic Office" 2" Futura Style "S" steel letters on mounting pins	"	1)					
Sign - 3" Futura Style stainless steel letters on mounting pins - 2 "Men"; 2 "Women"	"	4)	6,013.50				
Sign - 2" Futura Style stainless steel letters on mounting pins:		)					
"Train Schedule"	"	1)					
"Telephone"	"	1)					
"Traffic Office"	"	1)					
Sign - 4" Futura Style of colorless plexiglass mounted on wood backing:		)					
"Ticket"	"	1)					
"Luggage"	"	1)					
Speaker System							
Microphone RV 830	"	1)		Loud speaker system	Lot	1	469.58
Speaker, Jensen JH 20	"	3)					
Transformer, Jensen ZY 4001	"	3)	469.58				
Amplifier AV 35	"	1)					
Cable #14 AWG Braid X	Lin. Ft.	200)					
Total Passenger Depot			$144,380.84	Total Passenger Depot			$144,380.84

ACCOUNT 16 - STATION AND OFFICE BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions (continued)							
Mail Depot, brick, concrete floor, 3'6" roof overhang supported by joists, interior finish face brick, painted, openings overhead steel doors and windows, downspouts galvanized iron pipe, tar and gravel roof.							
Building 20'9"x 94'7" x 12'10"	Cu. Ft.	25,135					
Foundation							
Excavation, common	Cu. Yd.	59		Mail dock 20'9" x 94'7" brick, tar and gravel roof, concrete founuation and galvanized iron downspouts with 2'5" x 88'7" nigh outside concrete platform			
Backfill, common	"	51	13,518.99				
Concrete, plain	"	18					
" reinforced	"	50			Each	1	13,772.67
Reinforcing steel	Lb.	2380					
Platform							
Portion of concrete floor of mail room extended outside of building 2'5" x88'7" x3' high, 10½" concrete	Sq. Ft.	214	253.68				
Lighting							
Wiring in conduit	Outlets	30		Electric lighting at mail dock	Lot	1	2,525.53
Fixture - Art Metal No. 478 recessed incandescent reflector QUAD RLM 8145V	Each	8	2,525.53				
Sundry Items							
Sign - "Lubbock" porcelain enameled blue vitreous steel face letters, stainless steel sides, incandescent lamp back of each letter	Each	1	425.00	Electric signs at mail dock	Each	1	425.00
Total Mail Depot			$16,723.20	Total Mail Depot			$16,723.20
Paving and Sidewalks							
Concrete 5" with 3" to 6" earth base	Sq. Yd.	439		Concrete sidewalks and concrete paving and curbing.			
" curbing 7" x 24"	Lin. Ft.	588	2,635.35		Lot	1	2,635.35
" " 7" x 26"	"	111					
" " 8" x 30"	"	471					
Driveway 1½" Saturock topping on 6" caliche base	Sq. Yd.	266	664.75	Driveway 1½" Saturock on 6" caliche base	Sq. Yd.	266	664.75
Landscaping							
Evergreen trees	Each	3		Station ground landscaping - shrubbery and blue grass lawn.			
Flowering perennials	"	846			Lot	1	2,006.97
Perennials	"	88	2,006.97				
Lawn blue grass	Sq. Ft.	3,020					
Peatmoss, large bales	Each	10					

ACCOUNT 16 - STATION AND OFFICE BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions (continued)							
Miscellaneous pipe lines and water lines				Outside water lines			
3" C.I. pipe, flanged, with fittings, 20" trench	Lin. Ft.	191		Cast iron pipe 3" flanged, and fittings	Lin. Ft.	191	
2" C.I. pipe, screwed, 20" trench	"	68		" " " 2" screwed " "	"	68	761.29
3" gate valve, Mueller No. A-24805	Each	3					
Valve box, C.I., Buffalo	"	2					
			1,153.16				
Sewer and Drain Lines				Outside sewer lines			
5" Vitrified tile, 20" trench	Lin. Ft.	48		Vitrified tile 6"	Lin. Ft.	48	
4" " " 20" "	"	39		" " 4"	"	39	128.64
4" W.I. pipe, S.H.	"	32		Wrought iron pipe 4", S.H.	"	32	52.00
Gas Line				Outside Gas Lines			
2" black pipe, 14" trench	Lin. Ft.	131		Black pipe 2"	Lin. Ft.	131	211.23
AFE 52-52			$167,564.27	Total A.F.E.			$167,564.27
Wood Platform							
Foundation				High wood platform 28' x 72' creosoted pile head foundation, 6' x 28' incline			
Pile heads, pine, creosoted	Lin. Ft.	270					
Lumber, pine, creosoted	M.B.M.	0.672					
Deck 2" pine on 2" x 12", 12' centers on 6" x 8" caps 28' long 3' centers - 28' x 72'	Sq. Ft.	2,016		Plan CEOA 4453	Each	1	801.00
Boxing and Bracing							
Lumber, pine, creosoted	M.B.M.	0.180					
" " untreated	"	0.860					
Incline 6' x 28', 2" pine on 2" x 12", 12' centers on two 7" x 16" stringers	Sq. Ft.	168					
Driveway - embankment	Cu. Yd.	66					
AFE 70-24 Plan CEOA-4453			$801.00				
Track scale 46', Fit 7'5" x 46' x 7'3" deep; Beam Pit 5' x 7'6" x 7'6" deep				Track scales 46' 150 ton Fairbanks Type "F" style 24, 4 section with registering beams Code No. 6509 on concrete pit with 8' x 13' frame scale house. Plan CEOA #4083	Each	1	4,248.55
Scale 2xT Fairbanks, type "F", Style 24, 4 section with type registering beam, Code No. 6509, capacity 150 ton	Each	1					
Excavation, common	Cu. Yd.	228					
Concrete, plain	"	123					
Timber, pine, untreated 12"	M.B.M.	2.075					
Steel weigh bridge and scale supports	Lb.	25,550					
Cast iron dead rail	"	5,920					
Scale house, frame, wood floor, ceiling inside, composition roof							
Building 8' x 13' x 9'6"	Cu. Ft.	938					
Foundation							
Excavation, common	Cu. Yd.	2					
Concrete	"	2					
AFE 127-16 Plan CEOA No. 4083			$4,248.55				

ACCOUNT 16 - STATION AND OFFICE BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions (continued)							
Stock yards 65'6" x 65'3"				Stock yards wood 65'6" x 65'3" Plan CES #5134	Each	1	814.12
Lumber, untreated, pine	M.B.M.	4.821					
" creosoted, "	"	0.457					
Posts, creosoted 10" diam. x 10'	Each	46					
" " 10" " x 9'	"	16					
" " 8" " x 10'	"	2					
" " 8" " x 12'	"	2					
" " 8" " x 14'	"	2					
" " 8" " x 18'	"	2					
" " 8" " x 20'	"	6					
Pile heads, creosoted	Lin. Ft.	60					
Gates, 12', pipe frames	Each	3					
AFE 37-23 Plan CES No. 5134			814.12				
Combination freight and passenger depot, frame, stucco, creosoted pile foundation, brick trim around windows, double wood floors passenger, plastered inside, metal tile roof.				Combination freight and passenger depot 24' x 96' stucco on frame, pile foundation, metal tile roof with brick trim around windows Modified plan CES No. 5075	Each	1	6,406.72
Building 24' x 96' x 17'	Cu. Ft.	39,168					
Foundation							
Pile heads, creosoted	Lin. Ft.	251					
Lumber, creosoted	M.B.M.	1,820					
Platforms							
Elevated wood				High wood platform 20' x 65' foundation creosoted pile heads	Each	1	920.50
Pile heads, creosoted	Lin. Ft.	205					
Deck 2" pine on 2" x 12', 12" C to C on 6" x 8" pine caps 8' C to C	Sq. Ft.	1,312					
Station							
Embankment, common	Cu. Yd.	1,924		Station platform screenings 6" on earth fill, creosoted wood curbing on creosoted pile heads	Sq. Ft.	6,960	1,520.62
Screenings	"	120					
Curbing, pile heads, creosoted	Lin. Ft.	336					
" lumber, creosoted	M.B.M.	0.447					
" " " S.M.	"	1.227					
Furniture and fixtures							
Signs, waiting room	Each	2		Depot furniture and fixtures	Lot	1	180.45
Settees, Frost Johnson, 10' single	"	1					
" " " 8' "	"	4					
Bulletin board	"	1					
Lamps, kerosene	"	2					
Station sign "Lockney" letters 2" x 2" x 12' high	"	2					
Miscellaneous Pipe Lines							
Vit. clay 4", 5' trench	Lin. Ft.	86		Pipe line Vitrified clay 4"	Lin. Ft.	86	90.86
W.I. pipe 1", 5' trench	"	480		Pipe line Wrought iron 1"	"	480	262.40
AFE 90-25			9,381.55	Total A.F.E.			9,381.55

ACCOUNT 16 - STATION AND OFFICE BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Retirements							
Passenger station, 1 story, frame, Ready Roof, 20' x 40' x 14' av. hgt.	Cu. Ft.	11,200		Passenger station, E.R. page 152, item 6	Entire		6,425.00
Cesspool 9' x 9' x 6' deep, concrete	Each	1					
Low screenings platform	Sq. Ft.	260					
Coal house, 6' x 8' frame	Each	1					
(E.R. page 152, item 6)			6,425.00				
Screenings, platform	Sq. Ft.	520	147.50	(Same as now reported.)			147.50
(B.V. 588 period 1918-27, page 97, item 2)							
Improvements to Passenger Station				Improvements to passenger station, B.V. 588 period 1918-27, page 97, item 3, less previous retirements consisting of Arcola Heater, plumbing and furniture reported on B.V. 588 period 1946, page 86, item 2	Entire		3,427.82
Foundation: Excavation	Cu. Yd.	40					
Concrete, plain	"	20					
Building:							
Partitions sheet rock on two sides, 2" x 4" studs	Sq. Ft.	620					
Floor, reinforced concrete 5" thick	"	240					
Plumbing, 2 toilets, 2 lavatories, 1 urinal	Fixtures	5					
Lighting, wiring in conduit	Outlets	5					
Fixtures, 12" Globe	Each	4					
B.V. 588 period 1918-27, page 97, part of item 3			3,427.82				
Addition to Passenger Station				Addition to passenger station B.V. 588 period 1946, page 86, item 1	Entire		4,675.35
Frame, Ready Roof, on concrete foundation							
Building 20' x 20' x 14' av. hgt.	Cu. Ft.	5,600					
Foundation: Excavation	Cu. Yd.	50		Total A.F.E.			14,675.67
Concrete, plain	"	22					
Lighting, wiring in conduit	Outlets	10					
Fixtures, 36" Fluorescent	Each	4					
Heating, steam borrowed	Sq.Ft.Rad.	184					
B.V. 588 period 1946, page 86, item 1			4,675.35				
Total A.F.E.			$14,675.67				

ACCOUNT 17 - ROADWAY BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions							
Section house, 24' x 49' frame				Section house 24' x 49' frame on concrete foundation with concrete cellar, Johns-Manville asbestos shingle roof, equipped with bath room and fixtures and hot water tank and kitchen sink Plan C.S No. 6035	Each	1	6,130.86
Foundation:							
Excavation common	Cu. Yd.	56					
Concrete plain	"	32					
Basement floor 4" concrete	Sq. Ft.	166					
Superstructure:							
Frame 24' x 49' 1-story, redwood drop siding walls, wood floor, Johns-Manville asbestos shingle roof, brick chimney, plastered inside Plan CES No. 6035	Cu. Ft.	16,756					
Plumbing:							
Bath tub 5' enamel, Crane C-3442	Each	1					
Lavatory " " C-2250	"	1					
Toilet, washdown vitrified china, Crane C-11181	"	1					
Kitchen sink 18" x 30" enamel " C-19230	"	1					
Hot water tank, 50-gal. std. Range boiler	"	1					
Septic tank:							
Septic tank, Dickey 2-cell 3' x 7' tile	"	1		Septic tank, Dickey 2-cell 3' x 7' tile with vitrified tile drains 6" - 79' and 4"-310'	Each	1	320.75
Grease trap " 24" x 36" vitrified tile	"	1					
Drain, vitrified tile 6"	Lin. Ft.	79					
" " " 4"	"	310					
Fence:							
Cyclone 42", 63-4" round x 7' creo. posts 8' C to C	"	486		Yard fence, Cyclone 42" on 4" x 7' creosoted posts 8' centers and two steel gates	Lin. Ft.	456	680.40
Gate, metal 42" x 3'-6" Cyclone	Each	1					
" " 42" x 10' "	"	1					
Water lines:							
Pipe, wrought iron galvanized 2"	Lin. Ft.	352		Water lines, 2" galv. 352' and 1"-20' including water barrel	Lin. Ft.	372	230.62
" " " " 1"	"	20					
Water barrel with pail	Each	1					
Total A.F.E.			$7,362.63	Total A.F.E.			$7,362.63
Bunk house reinforced concrete 21' x 119'				Bunk house, 10 room reinforced concrete, 21' x 119', corrugated iron roof Plan CECL No. 202-12997	Each	1	3,799.48
Foundation:							
Excavation earth	Cu. Yd.	6					
Earth fill under floor	"	57					
Concrete plain	"	13					
Superstructure:							
Bunk house 10 room reinf. concrete 21' x 119' corrugated iron roof Plan C.C.L No. 202-12997	Cu. Ft.	25,903					
Furniture and fixtures:							
Plan 202-12997 and specification Book No. 4	Lot	1					
Water closet 5' x 7' frame with inside toilets and shower Plan CECL 189-15184	Each	2		Water closet, frame 5' x 7' with inside toilet and shower Plan CECL No. 139-15184	Each	2	364.87
Cesspool 4' x 8' x 12' deep:							
Excavation earth	Cu. Yd.	14		Cesspool 4' x 8' x 12' deep with redwood cover	"	1	175.00
Lumber redwood	M.B.M.	0.640					

ACCOUNT 17 - ROADWAY BUILDINGS

As Reported	Unit	Quantity	Cost	Recommended Reporting	Unit	Quantity	Cost
Additions (continued)							
Section house 24' x 52' frame							
Foundation:							
Excavation earth	Cu. Yd.	25		Section house 24'x52' frame on concrete foundation, wood shingle roof, 5'x29' covered porch Plan CECL No. 150-16181	Each	1	3,462.75
Concrete plain	"	18					
Superstructure:							
Section house, frame 24'x52', conc. foundation, wood shingle roof, rustic sides and porch 5' x 29' Plan CECL 150-16181	Cu. Ft.	16,756					
Tool House							
Frame 12' x 16' Plan CECL 140-200	Each	1		Tool house 12' x 16' frame, creosoted pile foundation Plan CECL 140-200	Each	1	476.40
Water facilities:							
Drilled well 12" x 150' with 12" steel casing	"	1					
Pump house, frame 6' x 8' with concr. floor	"	1		Water facilities: Same as reported showing cost of individual items			625.00
Engine Fairbanks 2 HP type T walking beams	"	1					
Tank 8' x 11' Redwood	"	1					
Tank Tower, frame 18'x18'x26' high on concrete pedestals, 8"x8" post, 6"x6" braces - Plan CECL 109-13377	"	1					
Gasoline storage house				Gasoline storage shed: Same as reported			52.60
Frame 3' x 5'	"	1					
Outside piping							
Water line 1" galvanized iron in 6" trench	Lin. Ft.	122		Outside piping: Same as reported			240.35
Sewer line 4" vitrified tile in 2' trench	"	150					
A.F.E. 416-19			9,196.45	Total A.F.E. 416-19			9,196.45

ACCOUNT 23—WHARVES AND DOCKS

ACCOUNT 24—COAL AND ORE DOCKS

Dredging (Method used and disposition of material)	Cu Yd
Bridges, ferry transfer including machinery (Description and size, see Accounts 6, 44, 45)	Each
Pontoons (Kind and dimensions)	"
Dock and wharf constructions (Set up each structure separating sub and superstructure with brief description)	"
Breakwaters (Describe and separate each structure)	"
Buildings (See Account 16)	
Coal and ore handling plants (Describe and separate each installation. See Account 19)	"

For additional items, see other accounts. For larger plans, give plan reference. Care should be exercised in separating structures to conform with units as established Paragraph 15—General Instructions, R. and E. as amended.

ACCOUNT 29—POWER PLANT BUILDINGS

See Accounts 16 and 20.

ACCOUNT 35—MISCELLANEOUS STRUCTURES

See other accounts.

Part 2—Simplification of B.V. 588 Returns

While the completion report is known and understood by practically all railroad engineers, since it is essentially an engineering report of construction projects showing details of units, quantities, and costs, the summarization of these completion reports as required by the Interstate Commerce Commission into an Annual Report is not so well known.

The report called the B.V. 588 Return is essentially an annual summary showing the changes made in the physical property of a carrier since the date fixed for its basic valuation. It is prepared in considerable detail as prescribed in the orders of the ICC (Supplement No. 5 to Valuation Order No. 3).

Committee 11 believes that the detailed requirement may be simplified without affecting the essential nature of the report—by showing in a summary form and in engineering terms the quantitative and qualitative changes in the physical property of the carrier and the expenditures incurred in making them.

The committee's recommendations are shown below, in detail, for the groups of accounts mentioned.

1. Track Accounts

Account 8—Ties:

Under this account show the road ties, separating them only between treated and untreated, the units—Each. All other ties, such as switch, crossing, and bridge ties, should be shown in the aggregate, units—MBM, separate totals for treated and untreated.

Account 9—Rails:

Rails should be separated only as between new and relay, units—Gross Tons. Show in the description column the track feet added and/or retired.

Account 10—Other Track Material:

This account should be grouped under the following headings:

1. Turnout material, unit—Cwt. This group should include frogs, switches, guard rails, crossing frogs, slip switches, curve guard rails, etc.
2. Rail items, unit—Cwt, separated between new and relay. This group should include angle bars, patented joints, bolts, nutlocks, and rail anchors.
3. Tie plates, unit—Cwt, separated between new and relay.
4. Spikes, unit—Cwt.
5. All other items which do not lend themselves readily to conversion into Cwt., such as switch stands, switch lamps, switch locks, gage rods, rail lubricators, patented derails, patented bumpers, etc., not included in groups 1, 2, 3, or 4, unit—Each.

Account 11—Ballast:

No change.

Account 12—Track Laying and Surfacing:

No change.

2. Structural Property (Including Account 13)

Account 13—Fences, Snowsheds and Signs:

Fences—give a brief description. Unit—Lin Ft or Miles.
Signs—show total number. Unit—Each.

Account 16—Station and Office Buildings:

Structures should be reported individually and definitely located by towns, mile posts, survey station, or other references.

Small buildings (under $5,000)—Each building or structure, including attached platforms, should be described in detail, stating size, type of construction, kind of foundation and roof, mentioning any other important features or characteristics. For such buildings show "Cu Ft" or "Each" and total cost.

Large and important buildings—Describe in same detail as "Small buildings" showing "Cu Ft" or "Each" and cost (cost of building, attached platforms and foundation).

Additional items to be shown as follows:

Plumbing—general description and cost.
Heating—general description and cost.
Unit heaters—general description, unit Each, and cost.
Lighting—general description and cost.
Power lines (inside)—cost.
Loud speaker system—general description and cost.
Fire protection—general description, unit—"Heads," and cost.
Elevators and conveyors—general description, unit—Each, and cost.
Machinery and equipment—general description, unit—Lot, and cost.
Other important items—general description and cost.
Sundry items (other minor items)—general description and cost.
Furniture and fixtures (other than office equipment)—cost.
Office equipment—number of units and cost.
Tractors and trucks—number of units and cost.
Stock pens—size and type of construction. Unit—Each, and cost.
Track scales—size or capacity and type of construction, unit—Each, and cost.

Platforms structurally detached from building—description and size, unit—Sq Ft, and cost.

Paving (driveways, sidewalks, etc.), kind, thickness of base and wearing surface, unit—Sq Yd, and cost.

Fences—kind, unit—Lin Ft, and cost.

Wells, including casing—diameter and depth, unit—Each, and cost.

Water tank—size, kind and type of support, unit—Each, and cost.

Windmill—kind, make, diameter of wheel, kind and height of tower, unit—Each, and cost.

Outside lighting—number of lights, brief description, and cost.

Outside pipelines—kind of pipe and size limits, indicating underground or elevated, unit—Lin Ft, and cost.

Manholes (complete), unit—Each, and cost.

Cesspools (complete), unit—Each, and cost.

Mail cranes, trade name and kind, unit—Each, and cost.

Freight derricks and cranes—kind or make and capacity, unit—Each, and cost.

Landscaping—brief description and cost.

Remodeling, involving inside changes and rearrangements chargeable to A&B, of existing structures, not affecting type of structure—brief description (no units), and cost.

Grading, drainage, protection work, paving, etc.—see Accounts 3, 6, and 39.

Account 17—Roadway Buildings:

For buildings and appurtenances see Account 16—"Small Buildings," for large maintenance of way shops see Account 16 "Large and Important Buildings," and for machinery see Account 44.

Account 18—Water Stations:

For buildings and appurtenances, see Account 16.

Water tanks—brief description, showing kind, size, and cost.

Water treating plant—brief description and cost.

Pumping machinery (boilers, compressors, pumps, motors, etc.)—brief description, size, unit—Lot, and cost.

Water columns and diesel locomotive hydrants—kind, unit—Each, and cost.

Pipelines—kind and size of pipe, stating whether underground or overhead and description of supports, insulation and conduits where applicable. Cast iron pipe unit—Net Ton, and cost. Other pipe, unit—Lin Ft, and cost.

Dams, reservoirs and settling basins (see Accounts 3 and 6).

Drilled wells (size and depth including casing), unit—Each, and cost.

Dug wells and cisterns (give size and kind of wall), unit—Each, and cost.

Account 19—Fuel Stations:

Buildings and appurtenances—see Account 16.

Coaling stations, state type, trade name and model, storage and operating capacity in Tons, kind of elevators and conveyors, number of aprons and tracks served, give kind, description and capacity of sanding facilities, if any, and reference to plans. Unit—Each, and cost.

Service tanks, pipe lines and equipment—see Account 18.

Fuel oil station:

Oil storage tanks—kind and capacity, unit—Each, and cost.

Dike around tank—see Account 3.

Oil cranes or diesel fuel hydrants—kind and size, unit—Each, and cost.

Unloading station or towers—brief description and size, unit—Each, and cost.

Oil troughs—description, kind, and size, unit—Each, and cost.

Oil sumps—description, kind, and size, unit—Each, and cost.

Servatrain unit—brief description, unit—Each, and cost.

Oil unloading station or tower—brief description and size, unit—Each, and cost.

Equipment in fuel oil pump house—miscellaneous mechanical equipment—brief description, unit—Lot, and cost.

Fire protection:

Equipment in pump house: pump—kind, make, and capacity, unit—Each and cost. Foamite tank including fittings—kind, size, and capacity, unit—Each, and cost.

Foamite fire protection equipment including pipe lines, brief description, unit—Lot, and cost.

Account 20—Shops and Enginehouses:

Buildings and appurtenances—see Account 16.

Additional items not covered in other accounts:

Brick chimneys and smoke stacks on their own foundations—size and type of construction, unit—Each, and cost.

Turntables and transfer tables—pit—size and kind, unit—Each, and cost; table—type and size, unit—Each, and cost.

Tractors—kind, horsepower, unit—Each, and cost.

Outside pits, size, type of construction, unit—each, and cost.

Lorry and wheel tracks—description and length in Track Feet, and cost.

Outside platforms—see Account 16—platforms structurally detached from building.

Driveways—see Account 16.

Sanding plants—complete description, unit—Each, and cost.

Inside piping—size limits and kind, unit—Lin Ft and cost.

Wells and cisterns—see Account 16.

Pipe lines—see "Outside Pipe Lines" in Account 16.

Car washing machines—description, unit—Each, and cost.

Engine washing machines—description, unit—Each, and cost.

Additional items—other than above mentioned—description and cost.

Account 21—Grain Elevators:

Building—in same detail as Accounts 16 and 20.

Machinery—complete description and cost.

Account 22—Storage Warehouses:

Buildings—in same detail as Accounts 16 and 20.

Account 23—Wharves and Docks:

Dredging—show method used and disposition of material, unit—Cu Yd, and cost.

Bridges (ferry and transfer) including machinery—give full description and capacity, unit—Each, and cost.

Pontoons—kind and dimensions, unit—Each, and cost.

Wharves and docks—set up each structure separately with brief description and dimensions, unit—Each, and cost.

Breakwaters—describe and separate each structure, unit—Each, and cost.

Account 24—Coal and Ore Wharves:

See Account 23 for wharves and docks.

See Account 16 for buildings.

Coal and ore handling plants—each installation to be shown separately with description and cost.

Account 29—Power Plants:

See Accounts 16 and 20.

Account 35—Miscellaneous Structures:

See other accounts as applicable.

3. Other Structures

Account 5—Tunnels and Subways:
Account 6—Bridges, Trestles, and Culverts:
Account 7—Elevated structures:

No changes recommended in the present requirements for the above accounts.

4. Accounts Containing Predominantly Mass Property

Account 2½—Other Right-of-Way Expenditures:
Account 3—Grading:
Account 39—Public Improvements—Construction:

No changes recommended in the present requirements for the above accounts.

Account 26—Communication Systems:
Account 27—Signals and Interlockers:
Account 31—Power-transmission Systems:

While the committee recommends no changes in the present requirements for the above accounts, it urges the continued use and development of simplified types and adjustment units.

5. Machinery

Account 37—Roadway Machines:
Account 38—Roadway Small Tools:
Account 44—Shop Machinery:
Account 45—Power-Plant Machinery:

Each major machine should be briefly described, unit—Each.

Smaller machines—name of machine and number assigned by railroad, if assigned.

6. Overhead Accounts

Account 1—Engineering:
Accounts 71–77—General Expenditures:

No changes recommended in the above accounts.

7. Equipment

Accounts 51 to 58, both inclusive:

No changes recommended in the present requirements.

Report on Assignment 10

Uses of Photography in Railroad Construction and Maintenance Work

Collaborating with Other Interested Committees

C. B. Martin (chairman, subcommittee), W. H. Kiehl, W. A. Krauska, B. H. Moore, J. K. Morrissey, F. A. Roberts, E. W. Smith, J. E. Stein.

In addition to the extensive use of photography by the public relations, safety, claims, and other departments of the railroads in carrying out their various functions and responsibilities, photography in its many forms has been and can be particularly helpful to the railroad engineer. Accordingly, your committee submits as information the following final report in the gathering of information pertaining to the use of photography in railroad construction and maintenance work. The equipment available for such photography includes the following:

1. Miniature or 35-mm cameras which take either black and white or colored pictures. The black and white pictures can be enlarged to any convenient size. The colored pictures can be made into slides for projection, which are particularly adaptable for training programs.
2. Folding cameras, available in 2¼- by 3¼-in to 3¼- by 5½-in sizes. These are easily carried and stored, and the pictures, generally black and white, are large enough for ordinary use or can be enlarged for more detailed study.
3. A variation of the folding camera which produces a finished print in about a minute, available in 2¼- by 3¼-in and 3¼- by 4¼-in sizes. This type of camera enables the photographer to observe the results on the spot and to retake pictures if necessary. Additional prints and enlargements can be made from the originals.
4. Commercial cameras utilizing cut film or plates. These come generally in 4- by 5-in or 8- by 10-in sizes, and are especially adapted for program studies on large projects.
5. Moving picture cameras in either the 8- or 16-mm size. These camera take either black and white or colored pictures and are especially good for training programs and study of the uses of new machines and equipment.
6. Aerial photography, which is generally contracted for with outside parties.

The most generally accepted uses of photography, other than aerial, by the railroad engineer for design and construction are:

1. To show particular features in connection with location surveys, for design or layout of structures or yards.
2. Pre-construction and progress photographs.
3. For training and familiarization programs.
4. To show condition or special features of facilities to be rebuilt to aid in cost analysis of reconstruction.

5. To record emergency conditions on construction projects for more detailed study and future reference.
6. To show unsafe conditions as information for study and rectification.

The most generally accepted uses of photography, other than aerial, used by maintenance of way forces, are:

1. To show condition of bridges, buildings and other facilities needing repairs, for studies developing type of repairs needed and cost, and for presentation to management.
2. To record emergency conditions such as slides, washouts, derailments, etc., for studies in regard to prevention, cure and repair.
3. To show comparison of chemical weed-control programs by "before, during and after" series.
4. For training and familiarization program for new personnel and for new types of machinery and procedures.
5. To show unsafe conditions as information for study and for rectification.
6. For progress reports on lengthy programs.

The use of aerial photography can be subdivided as follows: Ordinary, aerial photography analysis, and aerial photogrammetry.

1. Ordinary aerial photographs can be used by railroad engineers for:
   a. Recording existing conditions for engineering studies, including the making of right-of-way maps to scale and for checking buildings and bridge schedules.
   b. Locating building sites, industrial sites or siding locations.
2. Aerial photographic analysis utilizing aerial photographs (vertical stereo coverage) and field inspection can develop the following information:
   a. Mapping of engineering soils classified as to texture.
   b. Depths to bedrock, classified as shallow (0–5 ft), medium (5–20 ft) and deep (over 20 ft).
   c. Physical classification of bedrock, including type of excavation and other special problems.
   d. Soil bearing capacities as good, fair and poor.
   e. Mapping of all organic materials such as muck, peat, swamp, and marsh, and the respective depths of each.
   f. Detailed drainage map of the entire area, including subsurface drainage and seepage zones, with special emphasis on culverts and fills.
   g. Depths of glacial drift or wind-blown material classified as in "b" above.
   h. Selection of specific well sites for ground water supply based on geological conditions.
   i. Mapping of areas subject to flooding and washouts.
   j. Mapping of problem areas such as sinkholes (classified as buried, active or inactive); slides; rock falls; potential slide and/or mass movement areas; boulder areas; areas subject to frost heave; permafrost and muskeg; caving; and areas of erosion.
   k. Mapping of all locations of sand and gravel deposits.
   l. Mapping of all deposits of common borrow.

Among the foregoing the most important uses of photography by the railroad engineer are:

a. Predict possible land slides and erosion.
b. Development of industrial sites, with the added advantage of secrecy.
c. Location of materials.
d. Aid in location surveys, developing not only the best routes insofar as grades and curvature are concerned, but also as to materials, river crossings and possible future industrial sites or mining areas.

3. Aerial photogrammetry—As there has been remarkable development in aerial cameras, photographic material and stereoscopic plotting equipment in recent years, photogrammetry is now established as a basic procedure in all types of map making from small scale and generalized exploration charts to the exceedingly detailed contour maps of construction sites. Its uses for the railroad engineers are:
   a. Survey of present right-of-way location.
   b. Survey for proposed lines.
   c. Survey of proposed sites.
   d. Survey of timber lands and other noncarrier properties.

Since photographic material is useful for future studies as well as for the purpose for which it was intended, it is the recommendation of the committee that an index be prepared of the photographic material available in the various departments of the railroad. It is further recommended that the index be placed in the library, chief engineer's file, or some other central location for future reference.

Committee 24—Cooperative Relations with Universities

W. H. Huffman, *Chairman,*
W. W. Hay, *Vice Chairman,*
W. S. Kerr, *Secretary,*
M. B. Allen
W. S. Autrey
J. B. Babcock
George Baylor
T. A. Blair
Armstrong Chinn*
H. B. Christianson, Jr.
R. P. Davis
J. F. Davison
G. H. Echols
O. W. Eshbach**
E. I. Fiesenheiser
R. T. Fortin
G. V. Guerin
C. E. R. Haight
W. E. Hiltebeitel
R. P. Howell
S. R. Hursh
A. V. Johnston
G. A. Kellow
Frank Kerekes
H. E. Kirby
T. R. Klingel
N. W. Kopp
J. W. Laurent
E. C. Lawson
B. B. Lewis
F. J. Lewis
H. S. Loeffler
R. E. Loomis
E. E. Mayo
R. W. Middleton
G. W. Miller
R. C. Nissen
L. M. Ogilvie
W. A. Oliver
J. F. Pearce
J. E. Perry
Dr. R. B. Rice
W. T. Rice
R. W. Ripley
V. J. Roggeveen
J. A. Rust
W. C. Sadler
P. S. Settle, Jr.
H. O. Sharp
John Stang
R. J. Stone
D. W. Tilman
R. D. White
T. D. Wofford, Jr.
Committee

* Died August 28, 1958
** Died March 4, 1958

To the American Railway Engineering Association.

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement, and
   (c) the use of the best techniques and methods for recruiting college and university students, these to be set forth in a guide.

   Progress report on (c), presented as information ..... pagt 598

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure by
   (a) cooperating with and contributing to the activities of student organizations in colleges and universities, and
   (b) presenting to students and their counselors a positive approach to the attractive and interesting features of the railroad industry and the advantages of choosing railroading as a career.

   Progress report, presented as information ..... page 613

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information ..... page 614

4. The role of engineering technicians in the railroad field.

   Final report, presented as information ..... page 619

5. Revise the brochure "The Railroad Field—A Challenge and Opportunity."

   Final report, presented as information ..... page 621

6. Procedures for orienting and developing newly employed engineering personnel.

   Progress in study, but no report.

7. Stimulate an interest by college and university staff members in current railroad problems and practices, including AREA membership.

   Progress report, submitted as information ..... page 631

THE COMMITTEE ON COOPERATIVE RELATIONS WITH UNIVERSITIES,
W. H. HUFFMAN, *Chairman.*

AREA Bulletin 548, January 1959.

MEMOIR

Armstrong Chinn

Armstrong Chinn, president of the Terminal Railroad Association of St. Louis, passed away at Barnes Hospital, St. Louis, August 28, 1958, following surgery.

Mr. Chinn was born in Dallas, Tex. on September 26, 1894, and received his technical education at Virginia Polytechnic Institute where he earned a B.S. degree in C.E. in 1915 and a C.E. degree in 1916.

Subsequent to his graduation from V.P.I. in June 1916, he was employed by the Chicago, Burlington & Quincy Railroad, and after serving with the Armed Forces in France during World War I, rose rapidly to the position of district engineer, maintenance of way in 1927. Two years later he became chief engineer of the Alton (now part of the GM&O) advancing to general manager in 1943, and to chief executive officer in 1945, the position he held at the time of his election in 1946 to the presidency of the Terminal Railroad Association of St. Louis.

Mr. Chinn joined the American Railway Engineering Association in 1920, and was very active in committee work, giving generously of his time to Committees 4, 5, 11, 13, 22, and 24 over the years. He was elected a member of the Board of Direction of the Association in 1940 and was President in 1947–1948.

Mr. Chinn achieved outstanding success as a railroad executive, and enjoyed an excellent reputation for his broad experience sound judgment, and administrative ability. Members of Committee 24 sincerely regret his untimely passing and will miss pleasant and friendly association with him. He leaves behind a great circle of friends and associates who feel deeply the loss in his passing.

A more complete memoir on Mr. Chinn appeared in the November 1958 Bulletin, No. 546.

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement

(c) the use of the best techniques and methods for recruiting college and university students, these to be set forth in a guide

J. F. Davison (chairman, subcommittee), R. T. Fortin, C. E. R. Haight, W. W. Hay, W. E. Hiltebeitel, R. P. Howell, W. H. Huffman, S. R. Hursh, Frank Kerekes, F. J. Lewis, R. W. Middleton, W. A. Oliver, J. F. Pearce, W. T. Rice, R. W. Ripley, V. J. Roggeveen, P. S. Settle, Jr.

Under Assignment 1 (c), your committee presents as information the following Student Recruiting Guide—Recommended Techniques to be Used by the Railroads in Recruiting College and University Students, with the expectation of making it available in reprint form at a later date.

STUDENT RECRUITING GUIDE

Recommended Techniques to Be Used by the Railroads in Recruiting College and University Students

Prepared by the
AMERICAN RAILWAY ENGINEERING ASSOCIATION
Committee on Cooperative Relations with Universities
59 East Van Buren Street
Chicago 5, Illinois

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Appendix:

Exhibits 1 and 2—Typical Interview Appraisal Forms

ACKNOWLEDGEMENT

In the preparation of this Guide, the publication of the National Society of Professional Engineers entitled "Criteria for Professional Employment of Engineers", and the "Code of Recruiting Practices and Procedures" of the American Society for Engineering Education, prepared with the cooperation of the Midwest College Placement Association, were of valuable assistance, which is hereby gratefully acknowledged.

STUDENT RECRUITING GUIDE

Recommended Techniques to Be Used by the Railroads in Recruiting College and University Students

A. ORGANIZATION AND GENERAL PROCEDURE FOR CONDUCTING A RECRUITING PROGRAM

1. To avoid several different departments making separate arrangements with the same universities, a recruiting coordinator should be designated, who should have as advisers senior officers representing each interested department. Top-level understanding and support are essential to successful recruiting.

2. The recruiting coordinator should be given responsibility to coordinate all university recruiting (for non-engineers as well as engineers). While there are advantages in having engineers recruit engineering graduates, a good administrator is required whether an engineer or a non-engineer.

3. The recruiting coordinator should be given assistance (through a committee) by a senior officer of each department employing university graduates.

4. All departments should advise the recruiting coordinator of their needs for university personnel (graduates, undergraduates for summer employment, cooperative students).

5. In conjunction with departmental advisers the recruiting coordinator should decide which universities will be contacted.

6. The recruiting coordinator should contact the selected universities, explain the method proposed for recruiting, space requirements, etc., and request suitable interview dates and scheduling arrangements. Most universities have a well organized placement office which will cooperate in making these arrangements, but it should be borne in mind that only a limited number of companies can interview on campus at a given time and notification well in advance is usually required. Many companies make their arrangements one year in advance (next year's schedule arranged during current year's recruiting).

7. The coordinator should inform the placement office concerning the broad categories of employment available, and the college degrees and other requirements for each. The submissions should be checked each year to ensure that the information supplied represents current requirements.

8. The coordinator should make personal contact with the placement officer at least once each year. If this is impracticable, no more than 50 percent of these contacts should be delegated to an associate. A knowledge of the placement office operation at individual universities can convert an annual "one-shot" recruiting operation into a year-around activity, as some students graduate at the end of each semester and frequently alumni use the university placement service to effect a change of employers.

9. Attractive company literature should be prepared for distribution to the students. In addition to outlining employment opportunities (avoiding overselling) such literature should state clearly any requirements of employment, such as medical examinations, union affiliations which may affect the student, etc.

10. Literature should be sent to the placement office for distribution. In certain instances arrangements can be made to obtain the addresses of the graduating class, thus permitting a direct mail contact which is usually more effective (see Sec. A, Para. 8 above). Contact may also be possible through interested faculty members or students' clubs and other organizations.

11. By special arrangement with placement offices or through previous personal contact with students, some element of pre-selection may be achieved through:

(a) sending employment specifications to placement offices;
(b) posting company bulletins;
(c) correspondence with seniors;
(d) maintaining contacts with deans and professors of civil, electrical and mechanical engineering schools;
(e) providing summer employment for undergraduates.

12. Carefully select the interviewers (see Sec. B). Where suitable interviewers are available from participating departments, they should be used and given authority to make immediate job offers. Where non-departmental interviewers are used (such as Personnel Department specialists) promising prospects should be referred to the department concerned, but when this is done the student should be advised of the outcome within two weeks.

13. The interviewers should be punctual. He should tell the placement office when he will arrive, and he should arrive no later than the designated time.

14. No more than two interviewers and preferably only one, representing the employing department should appear for each interview scheduled. Arrangements for more than two interviewers should be made well in ad-

vance, and only for reasons which are considered adequate by the placement office.

15. An interviewer who desires to contact a particular individual at the time of his interview visit should write that individual at least two weeks in advance, with a copy to the placement office.

16. The interviewer should not offer a student special payments, gifts, bonuses, or other inducements, nor should he compensate or favor a third party to prevail upon the student to accept a particular employment offer.

17. After a student has declined a job offer, the interviewer should renew his proposal only through the placement office. The employer is thereby prevented from annoying students who have accepted employment elsewhere.

18. The employer should invariably engage every student who has accepted the interviewer's offer. If the interviewer cannot commit his company, the additional screening requirements should be thoroughly explained to the candidate (see Sec. E, Para. (e)

19. If the interviewer's organization is unionized, or the department for which the student is to be engaged is unionized, the interviewer should tell the student if he will or will not have to join a union. Furthermore, the interviewer should give the student complete and detailed information as to how the union will affect his status if employment is accepted.

20. When both a parent corporation and subsidiary or affiliated corporations conduct interviews in the same college, the respective interviewers should clearly explain their missions and their connections, both to the placement office and to the students. Interviewers should make clear where, and by which unit or division or subsidiary corporation, the students are to be engaged.

21. Interviewers should very carefully follow the interview schedule agreed upon with the placement office. They should not detain any student beyond the specified time.

22. The interviewer should not hurry a student into making a decision concerning employment.

23. Much of the value of recruiting effort is lost unless a company returns year after year to the same colleges, thereby establishing their name with the faculty and through them the students. Use of university placement facilities implies a continuing responsibility toward the university. As a matter of courtesy, the University should be advised of all job offers to candidates interviewed on their premises, a copy of the letter written to the candidate usually being sufficient.

B. SELECTING THE INTERVIEWER

There is a tendency to select interviewers who are alumni of the colleges concerned, and who are as near the student's age as possible, which is acceptable, providing the interviewer:

(a) has a thorough knowledge of the company and its policies;
(b) has a thorough knowledge of interview procedure;
(c) can exercise forbearance while retaining control of the interview;
(d) has the ability to recognize the stigmata of various disabilities (advice should be obtained from company medical officer);
(e) knows the working conditions of the positions offered;
(f) has the ability to project his own interest in the company;
(g) does not "over-sell" or distort actual conditions;
(h) can convey that conditions are constantly changing without creating impression that he is insincere.

C. TRAINING THE INTERVIEWER

For some individuals selected as interviewers, little advance training is required, but no matter how perceptive the interviewer, familiarity and practice are essential if a conclusion is to be reached within the required time (20–30 min). Practice in the peculiarities of university recruiting can be obtained only through actual participation, but familiarity with some of the broader problems of interview contacts can be obtained by:

(a) a few days experience in company employment offices interviewing applicants for all types of jobs;
(b) consultation with company employment office supervisors;
(c) consultation with student counselors at universities offering such services to students;
(d) observing techniques used by radio and television interviewers;
(e) attending courses in personnel practices offered by adult education organizations;
(f) obtaining professional instruction from specialized management consultants.

D. TRAINING IN STANDARD INTERVIEW PROCEDURE

The principle of the standard interview is that the candidate's past history provides the best available measure of his future performance. When the candidate has had previous working experience, his reactions to the problems faced provide a basis for his evaluation, but in most cases university students being interviewed must be judged on the basis of their academic achievement, hobbies, sports activities, participation in student's activities,

etc. A suitable application form should be devised which will elicit a skeleton of information from the candidate and thus provide a basis upon which the interview can develop. To standardize this step, many colleges insist on using the "College Interview Form." If the use of your own form is permitted, make sure that it can be completed by the candidate within 5 min and that questions not pertinent to the interview are excluded.

The following paragraphs (a) to (h), incl., are a guide to the information which should be obtained during a 20- to 30-min interview. The order in which paragraphs (c) to (h), incl., are presented does not indicate their relative importance, but may provide a guide to the order in which the interview might be expected to progress.

(a) The interviewer should introduce himself, welcome the candidate and offer a chair. A table need not separate candidate and interviewer but does provide a more businesslike atmosphere.

(b) From information on the interview form the interviewer must find some field on which the candidate is willing to discourse freely. This is a necessary prelude to more detailed and sometimes personal discussion.

(c) Develop previous work history:
1. Previous jobs and their responsibilities.
2. Any jobs he didn't like and why.
3. Did he leave any jobs; if so, determine reasons (dissatisfaction, pay, working conditions, friction, temper, etc.).
4. Does work experience indicate adaptability, inflexibility or is he a floater.

(d) Develop personal history regarding maturity:
1. Work after school, etc. (sense of responsibility).
2. Amount of family guidance or domination accepted.
3. Lived or worked away from home.
4. Reason for applying for interview.

(e) Develop personal history items regarding sociability:
1. Participation in community or student organizations.
2. Participation in group sports or recreation.
3. Interested in people as individuals.
4. Ability to get along with others (friendly, sense of humor, etc.).

(f) Develop personal history regarding leadership:
1. Any elected office in student or community affairs.
2. Prefer elected office of secretary, in preference to president.
3. If leadership offered would he dominate or inspire by example.

(g) Develop personal history items regarding manner and appearance:

1. Mannerisms (use of hands, facial expressions, etc.).
2. General appearance (dress, cleanliness, etc.).
3. Cultural background (parent's occupation and interests).
4. Voice and speech (irritating, high pitched, resonant, etc.).
5. Physical qualifications (any disabilities?).
6. Emotional stability (nervous, high-strung).
7. Aggressiveness, self confidence (forceful speech, positive manner, conversational initiative).

Note: Self confidence is usually reflected by poise, objectivity and competence, and should be distinguished from overconfidence which is reflected by overstatement, bluffing, etc.

(h) Develop personal history regarding emotional stability:

1. Home conditions (parental relationships, privations, etc.).
2. Adolescence (sports activities, etc., or lack of outlets for energy).
3. Recreational activities satisfactory for balanced life.

E. METHODS TO BE USED IN SELECTING ACCEPTABLE CANDIDATES

(a) In general, the employer wishes to determine:

(1) the level of aptitude;
(2) general proficiency;
(3) personality.

(b) The screening process may combine one or more of the following steps:

(1) The initial interview at the university at which a reasonably skilled interviewer can form a judgment of general proficiency and personality. For some positions, successful completion of academic studies is sufficient indication of their level of aptitude, but some positions may require further screening. In some instances, the universities will release the class standing of individuals in whom companies show a particular interest.

(2) A second interview (usually confined to individuals applying for positions requiring special skills), which may take the form of an off-campus interview with a senior officer of the employing department, or which may take the form of pencil and paper tests conducted either on or off campus. In the latter case, specialists should be used both to select the tests and to interpret

the results. Large organizations may have suitable specialists employed in their personnel departments, failing which numerous management companies are available which offer these services to the public. The recruiting coordinator can usually obtain guidance in this matter from any university which maintains a students counseling service.

(3) A plant visit. While this is frequently regarded as a device for "selling" the company, to a skilled observer it provides an opportunity to determine the recruit's reaction to actual employment conditions.

(c) For the purpose of this guide, it is assumed that railway representatives conducting interviews will use standard interview procedure for the initial interview (all pencil and paper tests being conducted by specialists) in which case all that is required is an evaluating form and some training in its use. Typical evaluation forms are presented herewith as Exhibits 1 and 2 (See Appendix).

(d) The evaluation form should not be filled out in the presence of the candidate but the interviewer should reach a conclusion regarding each factor and record his findings immediately upon concluding the interview.

(e) A copy of the evaluation form should be forwarded to the employing department for validation in the event a job offer is made, or for selection (or further interview) in the event no job offer is made.

F. COMPANY POLICIES WHICH PRODUCE THE MOST SATISFACTORY CLIMATE FOR ENGINEERING EMPLOYMENT

1. Recruiting

(a) Prior to exploring outside sources for candidates for higher positions, presently employed engineers should be evaluated and screened as potentially qualified candidates.

(b) Advertisements and announcements should state company name, realistic educational and experience requirements, duties of position and approximate level of remuneration.

(c) When interviewing prospective employees, a full and accurate description should be given of the type and scope of work, monetary benefits (including fringe benefits), training programs, opportunity for advancement, reason vacancy is being filled, anticipated duration of position, and a description of the engineering organization.

2. Inndoctrination

Some indoctrination is required, the period varying with the type and level of position being filled. It should cover the nature of the business,

introduction to company or department leaders and associates, organizational structure, company policies, professional responsibilities in matters of ethics, registration and membership in professional and technical engineering societies.

3. Technical Development

Additional training should be encouraged in order to broaden the technical qualifications of the engineer. The company should promote the fullest use of available courses by its engineering staff and should provide incentives as extensive as possible.

4. Administrative Development

As part of the company team, the engineer should be generally familiar with the business aspects of the company, and where he shows an inclination and aptitude to move into the administrative side of company operations he should be given appropriate opportunities. Good communication between management and the engineer is essential.

5. Professional Development

The company should provide a climate in which the engineer is recognized as a professional man and should provide inducements for his assumption of full professional responsibility. Registration should be encouraged and time off provided for refresher courses prior to examinations.

6. Personality Development

Periodic progress reports on individual accomplishments (or failures) should be provided. Social and civic activities should be encouraged.

7. Company Practices

(a) Working conditions. Clerical and semi-technical assistance should be provided. Suitable office accommodations and equipment should be supplied. While most engineers do not require private offices, their work demands a minimum of congestion and noise.

(b) Salaries should be paid monthly (or semi-monthly), and not on an hourly basis. Salary structure should be comparable with other industry and community rates for similar positions.

(c) Personnel administration for engineers should be separate from general personnel administration and should be in keeping with professional principles.

(d) Engineering titles should be granted to those who are qualified as engineers and who are doing engineering work, and to no others.

(e) Termination interview procedure should determine reasons for leaving employment so that reasons not the fault of the engineer may be eliminated. If an engineer cannot be retained, the employer should do nothing to impede his transfer to other employment.

APPENDIX

EXHIBIT 1
Page 1

TYPICAL APPRAISAL FORM

NAME (Surname first) ..... AGE .....

UNIVERSITY ..... COURSE & YEAR .....

"A"	"A" Applies	Tendency to "A"	Average	Tendency to "B"	"B" Applies	"B"
1. APPEARANCE AND BEARING Erect; alert; self-assured; well groomed; neatly dressed.						Awkward; diffident; sloppy and untidy; listless; slouches
2. AMBITIONS: Ambitious along well defined lines indicating maturity; not only wants to get ahead but to develop as a person; wants to make a contribution as well as to be rewarded.						Ambitions are shallow and vague; show lack of vision and maturity; his aims are self-centered; he expects too rapid advancement; he is only interested in initial salary; impresses as opportunist.
3. INTERESTS: His interests are well developed and are not confined to his immediate occupational or educational environment; they should broaden his perspective; they suggest maturity for his years.						His interests are few and seem shallow; they are not to his credit considering his age and opportunities.
4. FACILITY AND EXPRESSION: His diction and enunciation are good, his voice is pleasant and persuasive; he is able to organize his thoughts.						It is difficult to get him into conversation; his diction is poor; his choice of words is limited; he has an uninteresting voice.
5. PERSONALITY. He impresses as being of a warm and friendly nature; his outside interests suggest he gets along well with others; he has an easy, friendly, yet sincere manner; his behaviour in interview and phrasing of answers show tact; he puts himself in the other man's shoes.						He seems to lack friendliness; his approach in being interviewed is mechanical and insincere; his outside activities suggest he may lack the ability to get along with others; he appears taciturn and backward; his answers to questions show lack of tact and little regard for the feelings of others.
6. CONSCIENTIOUSNESS AND INTEGRITY: He is straightforward and frank in his answers to questions; he can be relied upon to carry out assignments; he would respect confidences; would honour agreements and keep his word.						He is evasive in answers to questions; there is evidence he is a slacker; could not be relied upon to carry out assignments; would be indiscreet in regard to confidences.
7. DRIVE AND DETERMINATION: His educational progress and other achievements suggest he is persistent and can follow through; he has not allowed handicaps or difficult conditions to prevent him from achieving his goal						He frequently starts new projects, particularly interesting ones, but rarely sees them through; he has made poor use of opportunities.
8. INTELLECTUAL QUALITIES: He is quick to separate the wheat from the chaff; he is quick to comprehend the meaning of questions, his interests suggest intellectual curiosity and a questioning mind; his academic record is good; he reasons on a sound logical basis and has a sense of proportion.						His attitude is poor; he bases his judgments on irrelevant and immature considerations - they disregard sound logic or the facts; he lacks intellectual curiosity; he is prepared to accept his environment as is; his interests are escapist and recreational only; he lacks resourcefulness.

EXHIBIT 1
Page 2

APPRAISAL SUMMARY

1. AT WHAT PLACES WILL APPLICANT ACCEPT EMPLOYMENT:
(a) Home town only. (b) Out of town, although reluctantly, or (c) Quite prepared to go anywhere .....

.....

2. IS APPLICANT PREPARED TO TRAVEL:
(a) Will not accept any travel (b) Not too fond of travelling but does not mind occasional trip, or (c) Likes travelling and would look forward to frequent trips .....

.....

3. ACADEMIC STANDING.
(a) This applicant stood ..... out of class of.....students in his final examinations in his last complete academic year.

(b) This applicant stood ..... out of class of ..... students in his latest examinations in his current school year.

4. STRONGEST AND WEAKEST CHARACTERISTICS:
(a) What seems to be the outstanding quality about this applicant? (e.g., his academic standing, achievements, personality, ability to express himself, ambition and drive, character and integrity) .....

.....

.....

(b) What personal quality or characteristic is he least impressive in? (Even though you feel this may not preclude employment .....

.....

.....

.....

5. GENERAL:
Write a brief summary of student's qualifications, considering, (a) his potentialities, (b) his real occupational interests, (c) his ability to adapt to different types of work and working conditions, and (d) the degree of ambition and drive he possesses. Try to indicate which type of assignments he is best suited to, e.g., research, design, inside-administrative, field-administrative, operating - supervisory positions, etc. .....

.....

.....

.....

.....

.....

.....

.....

6. DID STUDENT SEEM POSITIVELY INTERESTED IN RAILWAY EMPLOYMENT: .....
7. WAS A DEFINITE OFFER MADE TO STUDENT: .....DID HE ACCEPT? .....
8. IF NO OFFER WAS MADE WOULD YOU RECOMMEND FURTHER CONSIDERATION BE GIVEN STUDENT: .....

.....

.....

DATE: ..... INTERVIEWER: .....

TO BE COMPLETED LATER AT DEPARTMENT:

Date confirming offer sent .....

Result of final consideration .....

APPENDIX

TYPICAL APPRAISAL FORM

EXHIBIT 2
Page 1

UNDERGRADUATE, GRADUATE, AND PROFESSIONAL APPLICANTS

Appraisal of _____
(Surname) (First Name) (Middle Name)

Appraised for _____ by _____
(Position and Location) (Print name)

---

1. Personal Adjustment

Self-confidence

1 2 3 4 5 6 7 8 9 10

passive, lacking in self-confidence, over-dependent — self-assured, assertive, a liking for people

☐ appears 'brow-beaten' — overly aggressive ☐

Emotional maturity

1 2 3 4 5 6 7 8 9 10

anxious, tense, irresponsible, irritable, hypersensitive — persevering, determined, stable, anxiety-free, able to accept responsibility

☐ trying too hard to please — too rigid ☐

2. Social Adjustment

Family

1 2 3 4 5 6 7 8 9 10

overly-dependent on family, or hostile to family help and guidance — developing healthy independence from family

Education

10 9 8 7 6 5 4 3 2 1

balanced, active campus life — all work, no play, or all play, no work, etc.

Employment

10 9 8 7 6 5 4 3 2 1

realistic, purposeful, 'learn by doing' — spasmodic, distasteful, 'only because I have to'

3. Interest in Railroading

1 2 3 4 5 6 7 8 9 10

none, casual, uninformed, opportunistic, unrealistic — informed, long-standing, realistic

☐ but willing and anxious to learn — but 'knows all the answers' ☐

4. Fitness for a Railroad Career

10 9 8 7 6 5 4 3 2 1

should be a stable, productive employee — probably will not adjust, may quit after short period

☐ even if uninspired and uninspiring — but might become outstanding if we can hold him ☐

EXHIBIT 2
Page 2

5. Academic Standing

☐ Top Third ☐ Middle Third ☐ Bottom Third

What type of assignment would the applicant be best suited to? (More than one may apply)

☐ research ☐ inside-administrative ☐ operating-supervisory
☐ design ☐ field-administrative ☐ staff (advisory)

Other (specify) ----------

What prompted this applicant to apply to this company (More than one may apply)

☐ member of immediate family a company employee.
☐ university recruitment programme.
☐ close friend a company employee.
☐ application solicited by a company employee.
☐ surveying the field, shopping
☐ response to an advertisement
☐ other (specify) ----------

If this applicant is not to be considered for employment, state exact reason(s) as concisely as possible ----------

---

DATE _____ SIGNATURE _____

ADDITIONAL COMMENT:

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure, by Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

B. B. Lewis (chairman, subcommittee), W. H. Huffman, W. W. Hay, R. P. Davis, G. H. Echols, T. R. Klingel, H. S. Loeffler, G. W. Miller, J. F. Pearce, J. E. Perry, R. B. Rice, W. T. Rice, J. A. Rust, H. O. Sharp, John Stang, R. D. White, P. S. Settle, Jr.

The activities of your committee on this assignment are indicated by the following excerpts from letters of committee members:

H. B. Christianson, Jr., assistant chief engineer, Chicago, Rock Island & Pacific Railroad spoke at an engineering lecture at the University of Illinois.

R. P. Davis, College of Engineering, West Virginia University talked with many individual students about the future open to engineering graduates in the railroad field.

G. H. Echols, chief engineer, Southern Railway System: "On May 6, 1958, we entertained the senior civil engineering class at the Georgia Institute of Technology, Atlanta, Ga., beginning at 8 am, with a meeting in the Assembly Room of the Southern Railway Building in Atlanta. Here we attempted to interest the seniors in adopting railroading as a career. For this purpose we exhibited several films showing our new yards in operation, mechanized timbering and surfacing gangs, and much of the mechanized equipment being used in our bridge work. In cases where the films had no sound track, a running commentary was made in explanation of the various machines and the reasons for their use. At the conclusion, a long period of question and answers was held."

W. W. Hay, professor of railway civil engineering, University of Illinois: "H. B. Christianson, assistant chief engineer of the Rock Island Railroad, spoke on the subject 'Engineers and the Railroads.' J. C. Jacobs, engineer maintenance of way, Illinois Central Railroad gave an interesting address and showed a film on continuous welded rail."

W. E. Hiltebeitel, supervisor methods and cost control, Pennsylvania Railroad has been in contact with two student groups during the past year.

Frank Kerekes, Michigan College of Mining and Technology, gave two lectures to college students.

W. S. Kerr, Northwestern University, had eight meetings with student groups and gave two speeches.

W. Thomas Rice, president and director, Atlantic Coast Line Railroad spoke to a student group at the University of Florida and a student assembly at Jacksonville University, Jacksonville, Fla. "My topic for discussion on such occasions deals primarily with the railroad industry and the part played by the young college graduate in this field."

H. O. Sharp, professor geodesy and road engineering, Rensselaer Polytechnic Institute taught a course in transportation engineering during the second term and devoted several days to railroad engineering.

R. J. Stone, vice president operations, St. Louis–San Francisco Railway: "During the fall and spring of each year, five members of our engineering department interview

senior engineering students in 20 midwest colleges and universities, explaining what the engineer can expect in the railroad field. Also, these people have assisted in presenting programs to student chapters, ASCE, using films obtained from the AREA explaining track construction and maintenance techniques. These programs have been well received."

B. B. Lewis, professor of railway engineering, Purdue University, taught a class of 25 in railway engineering. This group visited rail facilities in Lafayette, Ind.

T. D. Wofford, Jr., engineer of design, Illinois Central Railroad: "J. C. Jacobs, our engineer maintenance of way, addressed the Student Chapter of the American Society of Civil Engineers at the University of Illinois on May 7, 1958, and showed a film on the welding of continuous rail. A. L. Sams, principal assistant engineer, addressed the Student Chapter at Purdue University this year, also."

W. M. Jaekle, chief engineer, Southern Pacific Company gave illustrated talks on heavy railroad construction projects on the Southern Pacific before student groups both at the University of Illinois and Stanford University.

Several civil engineering students from nearby schools were guests of Committee 24 and the AREA at the annual banquet in March 1958, and were escorted through the NRAA Exhibit at the Coliseum.

During the year 1958, the slide sets developed by Committee 24, depicting railway construction and maintenance operations, were loaned to various railroads and schools a total of 16 times.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

E. I. Fiesenheiser (chairman, subcommittee), J. B. Babcock, G. Baylor, R. T. Fortin, G. V. Guerin, W. W. Hay, W. H. Huffman, J. W. Laurent, R. E. Loomis, F. J. Lewis, E. E. Mayo, R. C. Nissen, R. B. Rice, J. Stang, R. J. Stone, T. D. Wofford, Jr.

In March 1958, questionnaires were mailed to both railroads and engineering colleges throughout the United States in a survey to determine: (1) the extent of cooperative work-study programs now in effect as a joint educational effort of industry and universities; (2) to determine some facts regarding the railroad industry's present support of higher education; and (3) specifically, the supply and demand with regard to railroad jobs available to students during the summer of 1958.

The enthusiastic response to the survey by many railroads and colleges is evidence of the sincere desire for cooperation along some lines. In processing the data concerning 1958 summer jobs, the subcommittee found itself acting as an information clearing-house for employment information. The deadline date set for return of the questionnaires was April 15th. Data concerning summer jobs available were immediately tabulated and distributed to the engineering colleges on May 5th. As a result, many students obtained their first introduction to railroad work and, no doubt, some of them have become prospective future employees. Unfortunately, replies from some of the railroads were delayed and could not be included in the report to the college students.

Replies from some railroads indicated that, because of the currently existing business situation, it would not be possible to employ summer student help during 1958, even though such help was ordinarily needed. Also many applications were received in railroad offices remote from the student's home. In the future, it will be suggested that students apply for positions near their home localities, if work is available there.

Following is a summary of replies of the questionnaire sent to both railroads and

engineering college and universities, and a copy of the report made to college and university students, through their respective institutions, regarding summer employment opportunities for engineering students on the railroads.

Replies from Railroads

1. *Are engineering college students ordinarily desired for summer work?*

   Thirty-one railroads answered affirmatively.

2. *How many are needed during the summer of 1958?*

   A total of 137 jobs available was reported. Replies were also received as to type of work available and location. Information was also supplied as to responsible railroad officials to be contacted by applicants.

3. *Salary range.*

   Salaries offered ranged from $325 to $450 per month. The higher salaries were offered to applicants having previous railroad experience. Specific salary data were given under "job information" in the report to students.

4. *Other advantages of summer positions.*

   Among those listed were: expenses paid away from headquarters, commutation passes furnished, and seniority during the time spent in college.

5. *Describe any other student assistance program in effect or planned.*

   Of the railroads replying, 13 stated their support of cooperative educational programs at universities.

Replies from Engineering Colleges and Universities

1. *Are cooperative work-study programs maintained at the college?*

   Of those replying, 38 stated that such are maintained. Practically all engineering fields are represented.

2A and 2B. *Do railroads assist in sponsoring these programs, and what railroads?*

   From the replies received, 26 different railroads were listed as sponsoring these programs.

2C. *What total number of students are enrolled in railroad-sponsored cooperative programs?*

   From the replies, a total of 160.

2D. *What railroads pay the student's first year's tuition?*

   Eight railroads.

2E. *What railroads assist the student financially, and to what extent, in addition to providing work opportunities?*

   One railroad provides 3 four-year scholarships. Two provide one scholarship each. One railroad maintains scholarships for employees or for their sons.

3. *What railroads maintain graduate fellowships at the college, and to what extent?*

   No graduate fellowships were listed as provided by any of the railroads.

4. *Concerning students wanting summer railroad work:*

   The preliminary tabulation indicated 810 engineering students wanting summer railroad employment during 1958. These were in the categories of chemical, electrical,

civil, industrial, mechanical, metallurgical, and general engineering. As compared to the 127 jobs listed as available, the supply exceeded the demand by about 540 per cent.

Report to College and University Students, May 5, 1958, on Summer Railroad Work Opportunities for Engineering Students

(Salary data have been deleted, but such information was included in the original report.)

Recently a questionnaire was sent to various railroads to determine their need of engineering student help this summer. It was discovered that there is a considerable demand. If you are an engineering student wanting that all-important summer job, this is your opportunity to work for a railroad. You will not only earn some money but will gain valuable work experience and will learn something about railroad operation. You should write at once to one of the officials designated in the tabulation which follows, in which the railroads needing help are listed alphabetically. If you are successful in obtaining a summer job you should find the work both interesting and profitable.

This information is supplied as a service to university students and railroads by a subcommittee of the American Railway Engineering Association Committee 24—Cooperative Relations with Universities.

Railroad and Name and Address of Official	*Job Information*
Baltimore and Ohio Railroad ..... Mr. C. R. Riley, Chief Engineer Maintenance B & O Building Baltimore and Charles St. Baltimore 1, Maryland Phone: Lexington 9–0400, Ext. 640	*Civil Engineering Students:* 6 to 8 3rd-year men needed. Work consists of string-lining curves and miscellaneous field work. Expenses are paid while away from headquarters.
Bangor and Aroostook Railroad Co. ..... Mr. P. H. Swales, Chief Engineer Bangor and Aroostook Railroad Co. Houlton, Maine Phone: Houlton 2213	3 *Civils* needed (any year). Work in Houlton, Maine. New track layout, general surveying, general office work.
Chicago and Eastern Illinois Railroad Co. ..... Mr. I. A. Moore, Chief Engineer Chicago and Eastern Illinois R. R. Co. Danville, Illinois Phone: 4922, Ext. 62	2 *Civils* needed (any year) General engineering maintenance and construction. Expenses paid away from headquarters.
Chicago and North Western Railway ..... Mr. W. H. Huffman, Assistant Chief Engineer Chicago and North Western Ry. 400 W. Madison Street, Chicago Phone: DE 2–2121	*Civils* needed (2 second and 3 3rd-year men). Surveying, drafting, field work, at various division headquarters. Expenses paid if away from headquarters.

Railroad and Name and Address of Official	*Job Information*
Denver & Rio Grande Western Mr. E. B. Herdman, Director of Personnel 1531 Stout Street Denver, Colorado Phone: AC 2–5533, Ext. 345	*Civils:* 2 third and 1 4th-year man; *Industrials:* 1 3rd and 1 4th-year; *General:* 3 3rd and 1 4th-year man. Various locations Col. and Utah. Track and bridge-building gangs.
Detroit, Toleda and Ironton Railroad Co. Mr. C. L. Towle, Chief Engineer 4921 Calhoun Street Dearborn, Michigan Phone: LU 4–9000, Ext. 281	Normally 2 to 4 *Civils* employed Field survey crew in Michigan or in Ohio. Rodman, instrument man, or engineering draftsman. Expenses paid away from headquarters.
Illinois Central Railroad Mr. A. L. Sams, Principal Assistant Engineer 135 East 11th Place Chicago, Illinois	*Civils:* 21 needed (5 1st-year, 8 2nd-year, and 8 3rd-year men). *Electricals:* 4 3rd-year men. Work in Chicago, Champaign, Clinton, and Carbondale, Ill.; Waterloo, Iowa; Jackson and Memphis, Tennessee; Jackson & Vicksburg, Miss.; New Orleans, La.; and Paducah, Ky. Field and office work in Bridge, Building, Signal, Communication, Electrical, Maintenance Departments.
Missouri–Kansas–Texas Railroad Line Mr. T. S. Carter, Chief Engineer Missouri–Kansas–Texas Railroad Line 701 Commerce Street Dallas 2, Texas Phone: RI 7–0311	Civils: 5 needed (1 1st-year, 3 2nd-year, 1 3rd-year man). *Mechanical:* 1 3rd-year man. Work in Dallas, Texas and vicinity. Survey work.
Reading Company Mr. Harry F. Smith, Chief Engineer Reading Terminal Philadelphia 7, Pa. Phone: Walnut 2–6100, Ext. 317	*Civils:* 2 2nd-year men desired. Field work, such as surveying, in vicinity of Reading & Philadelphia. Commutation pass furnished.
Northwestern Pacific Railroad Company Mr. C. E. Neal, Division Engineer San Rafael, California Phone: Glenwood 4–9100, Ext. 32	Specific work opportunities are unknown at this time. However, inquiries are invited.

Railroad and Name and Address of Official	*Job Information*
Southern Pacific Company ..... Mr. W. M. Jaekle, Chief Engineer 65 Market Street San Francisco, California Phone: DO 2–1212, Ext. 21178	Normally about 10 new men are employed each year, preferably first or second-year students. Work out of San Francisco, Oakland, Sacramento, or Dunsmuir, California; Portland, Oregon; Ogden, Utah; Bakersfield or Los Angeles, Cal.; Tucson, Arizona; or El Paso, Texas.
Texas and New Orleans Railroad Company ..... Mr. L. A. Loggins, Chief Engineer Texas and New Orleans Railroad Company 913 Franklin Avenue Houston, Texas Phone: CA 2–1121, Ext. 320	Civils: 7 needed, with 2 or more years of training in college. *Mechanicals:* 7 needed, with 2 or more years of college training. Work out of various cities in both Texas and Louisiana. General engineering work and in civil engineering. Personal expense account when away from headquarters.
The Western Pacific Railroad Company ..... Mr. J. F. Pearce, Office Engineer The Western Pacific Railroad Company 526 Mission Street San Francisco 5, California Phone: Yukon 2–2100, Ext. 269	*Civils:* 6 sophomore and junior students needed. General field surveying and office drafting work first year. Expense paid on field-party work.
Grand Trunk Western Railroad Co. ..... Mr. C. J. Morris, Chief Engineer 131 W. Lafayette Blvd. Detroit 26, Michigan	*2 Civil Engineering Students* with 3 years. Work in various cities in Michigan with field engineers on yard and grade separation projects. Expenses paid away from headquarters.
Chicago, Rock Island and Pacific Railroad Co. ..... Mr. H. B. Christianson, Assistant Chief Engineer 403 LaSalle Street Station Chicago 5, Illinois	*8 Civil or General Engineering Students* (4–3 year, 4–2 year) for Engineer Aides in various division headquarters including Chicago, Rock Island, Des Moines, Kansas City, Little Rock and Ft. Worth. Expenses paid away from headquarters. Some positions now filled.

Report on Assignment 4

The Role of Engineering Technicians in the Railroad Field

D. W. Tilman (chairman, subcommittee), W. S. Autrey, George Baylor, W. W. Hay, W. H. Huffman, S. R. Hursh, A. V. Johnston, T. R. Klingel, N. W. Kopp, E. C. Lawson, H. S. Loeffler, J. A. Rust, W. C. Sadler, R. J. Stone.

In 1956, your committee made a study of the role of engineering technicians in the railroad field. The report is recorded in the Proceedings, Vol. 58, 1957, pages 664–667.

In a continuation of that study, a questionnaire was sent to 94 railroad chief engineers and maintenance officers and to 125 engineering colleges and universities to analyze the over-all effect of the engineering technician program and to determine the present and potential use of technicians by the railroads.

Of the 94 railroads, 48 or 51 percent responded, and of the 125 schools, 89 or 71 percent answered the questionnaire.

Colleges and Universities

(89 responses from 125 questionnaires)

The first four questions were designed primarily to determine what the colleges and universities think of the impact of engineering technicians upon the development, standards and outlook of the engineering profession and on employment of engineering graduates. With only a few exceptions or qualifications, the school respondents indicate agreement that engineering technicians have no adverse effect on the engineering profession or employment.

Railroads

(48 responses from 94 questionnaires)

1. Is the program of utilizing engineering technicians detrimental to the development of the engineering profession?

   Yes—5 or 11 percent No—42 or 89 percent

2. Will the hiring of technicians for certain types of railroad work eventually lower the standards of railroad engineering employment?

   Yes—9 or 19 percent No—38 or 81 percent

3. Will the hiring of technicians eventually develop a discouraging or frustrating environment for other engineering employees who have college degrees?

   Yes—7 or 15 percent No—40 or 85 percent

4. During the current period of renewed interest in progressive corporate research, and in view of the strenuous efforts of educational circles to promote more advanced thinking, do you consider it a backward step for corporations to establish a policy of hiring engineering technicians for certain types of work?

   Yes—3 or 7 percent No—42 or 93 percent

5. We employ only college graduates for engineering work and do not plan to depart from that policy.

   Yes—5 or 11 percent No—40 or 89 percent

6. Does the employment of engineering technicians for certain types of railroad work present an opportunity to secure needed qualified men?

   Yes—45 or 94 percent No—3 or 6 percent

7. Have you made use of engineering technicians, or engineers with less than a degree, in the past?

   Yes—44 or 96 percent No—2 or 4 percent

   a. If yes, in what specific capacities have they been employed? Work listed includes:

Structural draftsmen	Inspectors	Chainmen
Cost estimating	Draftsmen	Tracers
Track supervisors	Surveying	Layout
Investigations	Blueprinters	Rodmen
Instrumentmen	Map filing	Detailers
Statisticians		

   b. Has their performance been satisfactory?

      Yes—45 or 98 percent No—1 or 2 percent

   c. How many of these men have progressed in a reasonable time to positions of leadership and responsibility?

      Many—4 or 9 percent Some—28 or 67 percent Few—10 or 24 percent

   d. What was the starting salary differential between college graduates and those employed without a college degree?

None	8	$75–$125 monthly	1
10%–20%	2	$75–$150 monthly	1
25%	2	$100 monthly	3
$15–$25 monthly	2	$100–$150 monthly	1
$35–$75 monthly	12	$150 monthly	1
$75–$100 monthly	5		

8. If your answer to Question 7 is "No", do you believe the employment of engineering technicians is worth a trial for your railroad?

   The two railroads which answered this question indicated their forces are too small to employ technicians if college graduates are available.

9. What effect would the employment of engineering technicians, as recommended by AREA Committee 24, have

   a. On your efforts to employ (or advance) college graduates in railroad work?

      None—40 Some—5

   b. On the quantity and quality of work under your jurisdiction after an adequate period of training?

      None—26 Improved—10 Reduced—3

SUMMARY

The responses indicate that most of the colleges and universities are in agreement that the engineering technician program has no adverse effect on the engineering profession or the employment of college graduates. Most of the railroads report the same conclusion.

Only 11 percent of the railroads have a practice of hiring only college graduates. About 96 percent of the railroads have used engineers with less than college degrees and conclude that the employment of engineering technicians presents an opportunity to secure qualified men.

The railroads report that engineering technicians are used for many types of work in support of graduate engineers. The technician performance has been satisfactory and their progress meets reasonable expectation.

Eight railroads have been securing college graduates at the same rate of pay as technicians, but 30 railroads report starting salaries for college graduates from $15 to $150 monthly above those for technicians.

Most of the railroads believe the technician program has no adverse effect on efforts to employ college graduates, and after adequate training the performance of technicians has no adverse effect on the quality and quantity of railroad engineering work.

Report on Assignment 5

Revise the Brochure "The Railroad Field—A Challenge and Opportunity"

H. E. Kirby (chairman, subcommittee), J. B. Babcock, H. B. Christianson, Jr., G. H. Echols, E. I. Fiesenheiser, W. W. Hay, W. H. Huffman, A. V. Johnston, G. A. Kellow, F. J. Lewis, W. A. Oliver, H. O. Sharp.

This is final report, presented as information.

Prepared in 1955 to present railroad engineering to undergraduate engineers in a highly competitive field, the first edition of this brochure is believed to have served its purpose effectually.

In carrying out its assignment to revise the original edition, your committee recognized that:

1. The four-year interval between publication of the first brochure and the currently proposed second edition has seen the competitive situation intensified, thus requiring that
2. The railroads present their case in a most forceful manner.
3. In this general situation, the subcommittee should construe its assignment as requiring comprehensive treatment.

With this concept, the committee proceeded in the firm conviction that the text of the revised brochure should be not only definitive and informative but also emphatically convincing. Accordingly, the following proposed revised text was prepared, and along with a number of suggestions for changes in the general format of the brochure, and in specific illustrations, was approved by Committee 24. Subsequently, the revised text and other suggested changes were submitted to the Board of Direction of the Association at its meeting on November 7, 1958, with the recommendation that they be incorporated in a second edition of the brochure, to be published early in 1959, in sufficient quantity for distribution to the engineering colleges and universities of the United States and Canada over a three-year period. This recommendation was approved by the Board, which authorized the printing of 18,000 copies for distribution by the AREA, plus 2000 copies to be turned over to the School and College Service of the Public Relations Department of the Association of American Railroads in repayment of this number of copies of the first edition of the brochure purchased by that Service for its own distribution, and subsequently returned to the AREA, upon request, in order to permit the AREA to complete its 1957 distribution. Advised of this action on the part of the Board, and invited to participate in the distribution of the 1959 edition as it did in the case of the 1955 edition, the School and College Service of the AAR ordered 8000 additional copies of the new second edition. Thus, the total press run of the new edition of the brochure, as this report is submitted for publication (December 1), is expected to be 28,000 copies.

A Challenge and Opportunity for Engineering Graduates

THE RAILROAD FIELD

Railroads are the lifeline of the nation, indispensible in peace and in war. Almost no other industry has such a profound effect on the American industrial scene as the railroads. The railroad industry has a history of dynamic improvement.

Some of the more recent steps in this march of railroad progress include the wide application of electronic computers and integrated data processing; automatic control of trains in operation and in yard classification and assembly; microwave and carrier communications; television and radio in line, terminal, yard and marine operations; and the use of photogrammetry in location, construction, and industrial site planning. Many similar technical improvements still lie in the future.

Equal progress has been made in areas of human engineering and in dealing with the industry's most valuable asset—its personnel.

Your future— is in your hands

The railroad industry offers a challenge and opportunity to the engineering graduate.

You as an undergraduate engineer must make a decision. This decision is one of the most important of your lifetime. It sets the course for your future.

Although many fields of engineering practice may interest and appeal to you, in planning your future you should also look closely at the railroads. For here is an industry that has grown with our country and likewise has become more vigorous and far-reaching with the years.

Experience, knowledge and alert management have provided the strength and stability which form the foundation for the railroads. This heritage has produced an industry with firmness of character, progressive in concept, with a constant challenge of new problems and new ideas to serve the nation better, faster, safer and more economically.

For this industry the past is only a prologue to continued progress; it will continue to forge ahead, with its only limitation—and yours—being the imagination and ingenuity of the men associated with it.

Here is the story briefly, of this great basic industry and some of its engineering aspects. Let us now introduce you to fascinating career opportunities—and challenges.

Where engineers are in the railroad industry

Foremost in all railroad operations are the large group of engineering graduates whose backgrounds embrace practically every branch of technical activity.

To these men the railroads offer careers, both challenging and interesting—more challenging because of the diversity of the field and the complexity of problems constantly confronting them; more interesting because of the broad areas for creative work and self-expression.

Engineers are placed in all categories of design, research, supervision, operation and top management. Theirs is the responsibility for planning, construction, installation and maintenance of the properties that make up an investment of some $35 billion in plant and equipment. Applied research and design for constant improvement are in their hands.

These men enjoy their work; they are respected by their associates; they have prestige in their communities; and they are substantially rewarded, materially and intangibly, for their efforts.

A graduate engineer's fields of participation in a railroad career

This chart will be a helpful guide toward choosing a career that will reward both your educational effort and the personal requirements that are important to you, a career satisfying in progress as a part of a progressive industry, and satisfying in creative opportunity.

AREAS OF RAILROAD ACTIVITY IN WHICH ENGINEERING GRADUATES HAVE INTERESTING AND REMUNERATIVE WORK

	Arch.	*Chem.*	*Civil*	*Elec.*	*Indus.*	*Mech.*	*Mining*
Accounting and Valuation			X	X	X	X	
Automatic Yard—Design, Construction and Maintenance			X	X	X	X	
Automotive Supervision and Maintenance			X		X	X	
Bridges—Design, Construction and Maintenance	X		X	X		X	
Buildings—Design, Construction and Maintenance	X		X	X	X	X	
Communications—Design, Construction and Maintenance				X	X		
Cost Analysis and Control	X	X	X	X	X	X	X
Electronic Computer Applications			X	X	X	X	
Flood Control		X	X		X		X
Heavy Equipment and Roadway Machines			X	X	X	X	
Industrial Development	X	X	X	X	X	X	X
Locomotives and Cars—Design and Maintenance		X		X		X	
Marine Facilities—Design and Maintenance	X	X	X	X	X	X	
Materials Handling			X	X	X	X	X
Materials Reclamation and Conservation			X	X	X	X	
Materials Testing		X	X	X	X	X	X
Methods and Work Simplification		X	X	X	X	X	X
Mine Development			X				X
Operations Research	X	X	X	X	X	X	X
Public Works Coordination	X		X	X	X	X	
Railway Location and Construction			X		X		
Railway Operation			X	X	X	X	X
Real Estate	X		X		X		X
Research, Applied	X	X	X	X	X	X	X
Signals—Design, Construction and Maintenance				X		X	
Soil Mechanics			X				X
Timber Processing		X	X			X	
Tracks—Design, Construction and Maintenance			X		X		
Tunnels—Design, Construction and Maintenance			X		X		
Utilities—Design, Construction and Maintenance	X		X	X	X	X	X
Water Service and Sanitation		X	X			X	

Engineering

Engineering in the railroad industry is a complex field embracing all activities involved in the design, construction, maintenance and administration of roadbed, track, bridges, tunnels, buildings, docks, signals, communications, lighting, yards, terminals, utilities, shops, locomotives, cars, materials-handling and other facilities.

Construction

The engineering staff of a railroad is responsible for making surveys, preparing plans and supervising construction, modification or improvement of the physical plant and equipment. This includes new automatic classification and assembly yards, and the modernization of existing yards to meet increased traffic requirements or to take advantage of current developments for economy of operation. The staff is required also to locate, design and build tracks and other structures to serve additional industries.

Maintenance

One of the major activities of the railroad industry is maintenance of roadbed, track, locomotives, cars, bridges, buildings, tunnels, communications, signals, conveyors and marine facilities. Many new machines are being developed to improve quality of work, accelerate production, and to minimize costs of maintenance operations.

The maintenance staff of any railroad is an organization of specialists equipped to do a tremendous engineering job under all conditions. Railroads must of course build and maintain tracks in almost every conceivable location—from coastal plains to rugged mountains—which are crossed or bored—across prairies and swamplands, over or under rivers and lakes, to great centers of commerce with intricate networks of all forms of surface transport. The maintenance engineer constantly is finding better ways to do the job.

The maintenance engineering staff is concerned primarily with maintaining and improving the roadbed, track, bridges, buildings and the other facilities used with these basic components. In many locations cuts and fills must be stabilized, employing the principles of soil mechanics and requiring studies as to best procedures. Engineering and economic studies of the many factors are necessary to reduce curves or grades, to "daylight" tunnels, and to effect grade separations.

Main-line high speed track, including its superstructure of rail, ties and ballast, must be constructed to highest standards and maintained for the safest operation of passenger and freight trains, with maximum passenger comfort and minimum damage to freight. Railroads usually employ two groups of forces to carry out this work—one to handle the many maintenance operations, the other to carry out new or rebuilding work.

A railroad engineering staff is responsible for design, construction and maintenance in accordance with established standards, and also for the programming, supervision and inspection of the work of all these forces. Industrial engineering and methods studies are essential to the solution of many problems, including that of acquisition of labor-saving machinery and adoption of mass-production to speed up work, improve its uniformity and quality, and to reduce costs. Engineers on several railroads have designed entirely new labor-saving machines and reorganized work methods to minimize hand labor.

Bridges

Equally important as a responsibility of the engineering staff is the design, construction and maintenance of drainage structures, viaducts, trestles, piers, docks and projects involving grade separations from other surface transport lines. Essential to railroad operations, these structures must be engineered to function as planned, with safety and economy.

Bridges and culverts of every type are used by railroads. Thus all phases of such work are the responsibility of the engineer—from preliminary survey to determine proper location, size and type of structure, through design, construction, inspection, and

maintenance. Studies involving soil mechanics must precede the design of sub-structures. Analyses are required to select materials and methods which will result in economical construction and minimum maintenance costs. In some instances simple pile and timber trestles may be required, in others long, multiple through-truss spans will be necessary.

Existing bridge structures must be maintained in good condition. Field inspections are needed to determine what repairs may be required. The work of repair crews must be programmed, materials and equipment assembled, and the work supervised and inspected. New methods and labor-saving machines must be developed constantly to provide practical and economical methods of carrying out such maintenance programs.

Buildings

The problems of the design and construction of new buildings of all types for many purposes are handled by the Engineering and Architectural Staffs. New and modernized passenger stations are but one of the many responsibilities of the architect and building engineer.

For properly maintaining locomotives, modern locomotive shop buildings must be provided.

Passenger and freight car shops must be designed to handle all types of construction and repair to all classes of cars, while other shops are needed for rebuilding and modernizing existing rolling stock.

Storehouse facilities are required at many locations where thousands of kinds of materials, parts and supplies must be readily available daily.

Warehouses and freight-handling facilities must be provided in railway terminals to handle large volumes of less-than-carload freight with power equipment, including tractors and trailers, fork-lift trucks, conveyors, and other modern materials-handling devices.

Office and welfare facilities are needed at many key points to house personnel engaged in countless railroad activities.

Many other types of on-line and terminal structures, such as locomotive fueling, watering, sanding and cleaning facilities, and car loaders and unloaders, are required in connection with railroad operation.

The technical staff of a railroad must design and supervise the construction of all these facilities. Equally important, they must plan and carry out their maintenance.

Signal

The Signal Engineering Staffs of the railroads have the responsibility of providing and maintaining safely engineered systems of signaling capable of controlling the movements of a large number of trains at various speeds. These systems include centralized traffic control (CTC), wherein both signal lights and power switch machines over several hundred miles of busy tracks are controlled remotely from a single panel type control machine.

Electrical engineers of the signal staff design and install interlockings to control the movement of trains at busy railroad terminals and crossings. The control of a number of these interlockings may be consolidated under one operator seated at a console desk type control machine equipped with a miniature facsimile of the track layout. The various routes are controlled by push buttons or desk levers, and the train movements are indicated by miniature lights and automatically recorded by a train graph.

Signal engineers also design and install controls for automatic car classification yards. In these yards a train is pushed up an incline over a "hump"; from the apex of the hump the cars roll individually by gravity onto the various selected classification

tracks. The control operator merely pushes a button numbered to correspond to the track destination. The procedure then is competely automatic: Switches are positioned as cars advance to proper tracks; characteristics of tracks, car-rolling and distances are measured electronically; a computer instantly determines retardation required and effects the automatic control.

The signal engineering staff also has responsibility for the design, construction, maintenance and operation of the automatic train control systems, where the actual operation of a train may automatically be controlled to conform with signal indications. All highway–railway grade crossing gates and signals, and special devices such as rock slide warnings, hot box detectors and indicators, also are under the jurisdiction of the signal engineers. They are likewise called upon to make operational studies to determine the economics of new and improved signal systems.

Communications

An integrated system of dependable communications is vital to the operation of any railroad. Communication services provided must be economically justified through savings in operating costs, or through increased sales of a railroad's only commodity—transportation. Communications engineers are responsible for the evaluation of service requirements, design of facilities, and application of circuits and equipment to meet a railroad's ever expanding communication needs.

Communication services must be maintained in a condition that will assure continuous operation. In this fast-developing field, obsolescence cannot be tolerated. Communications engineers constantly are alert for the development and application of improved equipment and methods.

Railroad communications services include:

Voice communication channels to direct train operations, coordinate and effect supervisory control in yards, freight houses and offices.

Printing telegraph networks, to transport in addition to the usual intra-company messages, information of record on train movement from terminal to terminal for operational purposes, to traffic representatives for customer services, and providing as a by-product a punched tape for some forms of mechanized accounting.

Microwave and carrier telephone terminals, to provide numerous communication channels between important operational locations, divisional, regional or system headquarters.

Integrated data processing (IDP) communication channels of various capacity to handle slow, medium or high speed transmissions of data in digital form, for eventual use in accounting machines or electronic computers.

Radio in main line, terminal and yard operations, to enhance safety of operations and promote efficient use of motive power; in marine services on tugboats and ferries; on mobile equipment in shop areas and storerooms, and in miniature form in the pocket of car inspectors on routine duty, wherever efficiency can be improved through better methods of communications.

Television for remote checking of passing trains, surveillance of yard areas, observation of equipment operation, ticket reservation systems, and where extension of supervision's field of vision can provide improved operations.

Recording devices to store voice transmissions, for future use in compiling train lists, to provide continuous telephone attendance where nature of work may require personnel to be away from assigned location.

Mechanical

Mechanical engineers are confronted with a broad challenge. Theirs is the responsibility for the design, construction, maintenance and servicing of all types of rolling stock, and many features of the fixed plant.

The Diesel-electric locomotive today is the economic and efficient backbone of railroad motive power. Tomorrow it will probably be the gas or steam turbine, or atomic-power. Responsibilities and opportunities of the mechanical engineer include:

Developing improved means of keeping Diesel-electric locomotives in serviceable condition under many different and difficult operating conditions.

Devise and supervise better methods of servicing motive power at outlying points.

Improve shop practices; make more efficient use of plant and equipment.

Participate in new developments in modern high-speed locomotives and their many important components.

High-speed passenger and freight train operations over modern tracks and terminals have multiplied and changed the mechanical engineers' problems. New designs of cars to supply the special types required by shippers constantly are being developed. These include special flat cars to transport highway trailers in quantity (operation piggy back), flat cars for giant turbines and electrical fixtures, flat cars with fixed ends for several commodities requiring special design, mechanical refrigerator cars and many others now in process of development.

Mechanical engineers also are closely associated with the design of passenger cars capable of operating at speeds in excess of 100 mph. They must also assure that all air-conditioning, lighting and safety equipment function properly under all conditions, and that wheels, trucks, and electric and air-brakes meet the highest standards of safety and comfort.

The work of mechanical and industrial engineers is directly applied to work simplification, materials handling, and methods of building, rebuilding and modernizing cars; in devising best methods for servicing, inspecting and repairing cars in trains at terminals without delay; develop and approve bearings, brakes and safety appliances, and improve methods for their application; establish loading methods and rules to avoid derailments; and develop improved practices and more durable materials.

Electrical

The electrical engineer performs an important service in several railroad departments, including Mechanical, Signal, Communications, Maintenance of Way and Structures, and Engineering. With the ever expanding use of electricity in practically every phase of railroad operation, the opportunities become wider than ever before.

The railroad electrical engineer is responsible for the design and maintenance of:

Generators, traction motors, auxiliaries, and control equipment on Diesel-electric locomotives, all of primary importance on railroads today.

Power supply, air-conditioning equipment, lighting, inter-communication systems and other modern electrical conveniences on passenger cars.

Electric features of the fixed plant, which include lighting, power distribution, transmission lines, power substations, shop tools, electronic controls, electrolysis studies, and others.

Electronic computers, which are of increasing importance in data processing, accounting, and in the solution of a variety of engineering problems.

Catenary, transmission lines, substations and supervisory control, together with many problems of the electric locomotive and of multiple unit cars on electrified lines.

All of these responsibilities call for ingenuity, resourcefulness, and versatility on the part of the electrical engineer.

Research and Development

Engineering graduates in several branches of the profession whose primary interest is in the area of applied research will find interesting opportunities in railroad service.

Many railroads maintain staffs and modern laboratories, physical, chemical and metallurgical, fitted with up-to-date equipment. In addition, the railroads collectively operate ultra-modern laboratories in their own three large buildings situated on the campus of Illinois Institute of Technology at Chicago.

The work of these research engineers and scientists is of tremendous economic value to the several purchasing and consuming departments of the railroads in:

1. Quality control and utilization of the many thousands of commodities and types of materials.
2. Check design stresses in locomotives, cars, various types of bridges, buildings and track structures.
3. Analyze failures in structural materials, track fastenings, and locomotive and car components.
4. Development of more durable and damage-free shipping containers for liquids, solids and gases, of synthetic and natural materials.

The foregoing represents only a minute fraction of the total activities of this group. Thousands of such projects have been completed; hundreds of others currently are under way.

One of the most interesting of these current developments is in the field of nucleonics. The railroads are alert to developments in this and other subatomic physical processes.

For example, the installation of radioactive switch lamps which provide a safe, self-contained source of light for red, green and yellow signals. This light is expected to furnish a satisfactory signal indication, through radioactive Krypton 85, for 15 years with no maintenance expense.

Additional products of modern research include the use of other radioactive isotopes to trace wear of engine parts of locomotives to ascertain proper lubrication procedures. These investigations already have resulted in substantial cost reductions and increased railroad operating efficiency.

Studies of nuclear reactors, their shielding and adaptation to railway motive power, give promise of feasibility.

Other Opportunities in the Railroad Field

We have seen that in the several railway engineering departments, because of the nature of their work, the personnel necessarily consists almost entirely of engineers. There are also many other areas of railroad work in which engineering graduates find

a wide field of opportunity. Most of these are listed in the chart on page 623.

This chart does not, however, include all of the activities open to the graduate engineer. For those with specialized interests there are several additional fields which offer challenging opportunities. Specifically included are:

The Operating Department

which is responsible for providing safe, efficient, economical and on-time transportation, naturally offers some of the most difficult and challenging problems, and at the same time a most gratifying sense of accomplishment. All other departments, including all branches of engineering, really function as supporting elements that enable the operating department to provide transportation. In this department an engineering background is a decided asset. Engineers are placed in responsible positions throughout the range of railway operation from trainmaster to top management. Many railroad presidents began their careers as engineering subordinates.

The Accounting and Traffic Departments

offer increasing opportunities to engineers, as railroad accounting and cost controls, utilizing newest electronic equipment and methods, assume constantly increased importance, and as freight traffic solicitation in the present competitive era becomes more than a matter of rate structure and routing.

The Purchasing Department

is an organization in which men schooled in chemical, civil, electrical and mechanical engineering naturally find an interesting field of endeavor in securing for the railroads the many thousands of items of material of the right quality and design needed for their efficient operation.

The Real Estate Department

is using to great advantage the knowledge of the civil engineer in the appraisal, sale and purchase of property and the management of their extensive holdings, whether used for railroad operation or for industrial purposes.

The Industrial Development Department

of railroads offers opportunities for civil, industrial, architectural and other engineers to assist manufacturers in plant location, layout, and service trackage; to promote industrial growth and traffic through studies of natural resources in the territory served; and to foster agriculture, mining, forestry, stock raising and other enterprises in areas contiguous to railroad lines.

Most graduate engineers entering railroad service will begin under a formal or informal rotative plan designed to provide them with well-rounded basic training. Such a plan has several advantages. It permits early mutual acquaintance; it enables the engineer starting his career to learn about the manifold areas of railroad activities and interests; and it permits the company to observe the man, his actions and reactions in different situations.

This procedure enables the company to make the most effective use of his capabilities among the technical specialists of the railroad team.

Thus it follows that after mutual acquaintance and demonstration of qualifications, enterprising graduate engineers find wide opportunity for advancement in practically every field of railroad activity leading to executive positions in almost every department.

Special Advantages

In addition to the large and varied field of opportunities offered to the graduate engineer, the railroads also provide attractive direct compensation and many other indirect benefits, some of which are:

1. Recognition for work.
2. Interesting and diversified experience.
3. Encouragement for ingenuity and ideas.
4. High degree of job security.
5. Free transportation or reduced fare travel.
6. Professional association participation.
7. On most railroads free or low-cost group insurance and hospitalization are available.
8. Annuity benefits after retirement through the Railroad Retirement Board, and supplemented on many railroads by individual retirement plans.
9. Training plans, as discussed on page 629, by which casual treatment during early employment periods is avoided. These plans provide a formal, orderly and comprehensive procedure. Such training courses give participants an important start on the experience helpful in realizing the maximum from their technical education. Likewise, they provide the young engineer with a basis for determining his preferred area of activity.

What does a railroad career require of an engineer?

Railroading has entered a dynamic, new era of growth. Engineering talent is needed to develop and mold the procedures which will increase this growth, and provide for the railroads of tomorrow. Modern technology has opened new vistas of opportunity to the graduate engineer, presenting him with a challenge limited only by the limits of his own resourcefulness and initiative. The railroad field offers ample scope within which to apply his knowledge and to engage his thinking in creative productivity, to the end that, within his capabilities, he has an opportunity to make a significant contribution to railroads and science.

A high degree of specialization in one or more branches of the profession is not generally necessary for the engineer entering railroad service.

There is no inflexible specification, nor set formula, to describe precisely what attributes a young engineer shall bring to the railroad. In acquiring an engineering degree from an accredited school, he will have exercised personal disciplines and developed patterns of habit, thought and personality which should be of much benefit as he approaches and continues his professional career.

In addition to this background, professional advancement also will depend upon character, diligence and ability to work in harmony with associates. And, if the element of enthusiasm is added to these, no man can set a limit on the heights of achievement possible of attainment.

The Challenge and Opportunity of a Railroad Career can be Yours. To learn more, communicate with the Chief Engineers or Chief Mechanical Officers of the many railroad companies; or meet the railroad representatives interviewing students at your school, or call at any railroad division office or system headquarters.

Report on Assignment 7

Stimulate Greater Interest by College and University Staff Members in Current Railroad Problems and Practices, Including AREA Membership

W. W. Hay (chairman, subcommittee), W. H. Huffman, M. B. Allen, J. B. Babcock, T. A. Blair, R. P. Davis, G. V. Guerin, W. E. Hiltebeitel, R. P. Howell, J. E. Perry, V. J. Roggeveen.

Your committee submits the following report of progress.

The subject as assigned seems to pre-suppose a certain lack of interest in railroad matters on the part of college and university staff members. This may or may not be true. The committee believes that the first step should be to determine the attitudes of academic staffs and the reasons for those attitudes. With that data in hand the committee will be better prepared to suggest ways of stimulating interest. A questionnaire for this purpose is being mailed to the accredited engineering schools of the United States and Canada.

As a result of preliminary opinion sampling the committee feels qualified to make a few tentative suggestions as to how greater interest in current railroad problems and practices might be stimulated among college and university staff members, even before the questionnaire results are analyzed. These are as follows:

1. Prepare list of varied thesis topics related to railroad problems and suitable for bachelors, masters, and doctoral levels, to be made available to students and academic staffs. These topics should be realistic ones that would make a genuine contribution to the railway industry. There is no better way than by active participation to get people interested in something, and the beneficial effect in this case would be not only on the students, but also to their instructors and possibly on the railroads too. The committee will undertake to prepare and make available such a list.

2. Financial support, while not a necessary part of the foregoing suggestion, would aid in its effectiveness. The committee is not thinking in terms of large sums at this point—some really good experimental theses have been prepared in university laboratories at total expenditures for materials and equipment of $25 to $100—others of course cost thousands, still others involve only the supply of stamps necessary to secure information. Many universities have ample funds to finance almost any thesis topic related to highway research but none is available for railroad topics.

3. Every university staff member thus far contacted has recommended railroad participation in sponsored research, including a share of so-called "pure" research, as a means of keeping the railroads within the range of academic interest. It has been suggested that a certain amount of this would be valuable for publicity purpose even if no other benefits were to accrue. AREA members know that the railroads are sponsoring some university research projects. The reaction to this effort by university staff will, it is hoped, be seen in the replies to the questionnaire.

A further report will be made after the questionnaire data have been processed and the findings studied by the committee.

Report of Special Committee on Continuous Welded Rail

C. E. WELLER,
Acting Chairman,
F. L. REES,
Vice Chairman,

R. E. DOVE, *Secretary,*
FRANK AIKMAN, JR.
J. D. ANDERSON
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R. A. SHAROOD
T. C. SHEDD
H. A. SIRAVO
R. P. WINTON
EDW. WISE, JR.
Committee

* Chairman until his resignation on October 21, 1958.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Fabrication.

   Progress in study, but no report.

2. Laying.

   Progress report, presented as information ..... page 634

3. Fastenings.

   No report.

4. Maintenance.

   No report.

5. Economics.

   Progress report, presented as information ..... page 637

Special report on welding rails at or in vicinity of rail mills, presented as information ..... page 640

Special report on field tests on continuous welded rail on Great Northern Railway, presented as information ..... page 642

THE SPECIAL COMMITTEE ON CONTINUOUS WELDED RAIL,
C. E. WELLER, *Acting Chairman.*

AREA Bulletin 549, February 1959.

Report on Assignment 2

Laying

E. J. Brown (chairman, subcommittee), W. H. Freeman, H. F. Gilzow, R. A. Hostetter, T. B. Hutcheson, A. B. Lewis, C. R. Merriman, B. M. Monaghan, F. L. Rees, C. E. Weller.

This is a progress report, submitted as information.

The total mileage of continuous welded rail laid by the railroads of the United States and Canada as of the end of 1958, by years, is as follows:

Year	*Track Miles*	*Year*	*Track Miles*
1933	0.16	1949	33.05
1934	0.95	1950	50.25
1935	4.06	1951	37.25
1936	1.52	1952	40.00
1937	31.23	1953	80.00
1939	6.04	1954	87.00
1942	5.48	1955	266.50*
1943	6.29	1956	461.43*
1944	12.88	1957	550.12*
1945	4.81	1958	460.24*
1946	3.91		
1947	18.70	Total	2191.80
1948	29.93		

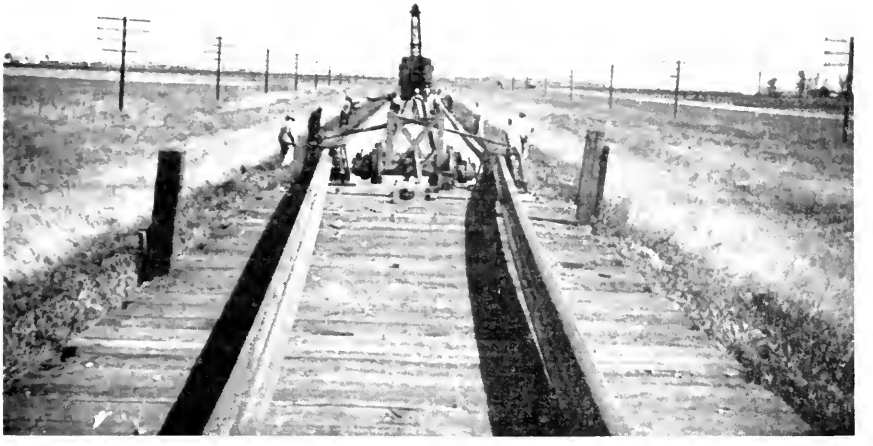
* 1955— 72 miles were electric-flash butt welded.
* 1956— 89.10 " " " " " "
* 1957—159.65 " " " " " "
* 1958—312.13 " " " " " "

The techniques of laying continuous rail have changed very little in the past several years, and the same is true of the organization of the rail laying gangs.

Picking Up Long Strings of Rail For Laying in Another Location

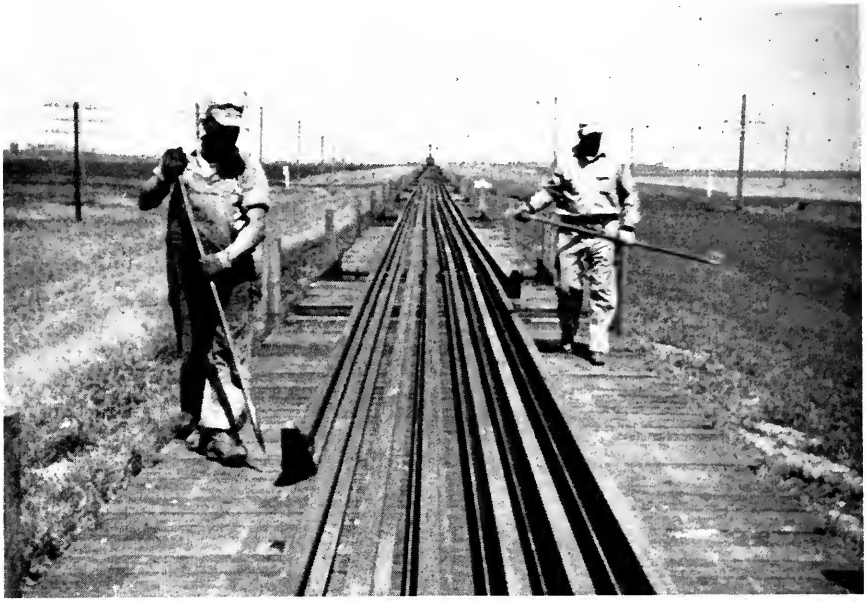
During the early years of laying continuous welded rail on railroads, many were apprehensive as to how the long lengths of rail could be removed from where they were laid originally and transported to other locations, should such become necessary or advisable. A solution of this problem is seen in the experience of one large railroad—the Great Northern—which, because of a change in plans, found it necessary to reload 32 strings of continuous welded rail for movement to another location about 225 miles away. These strings of rails, each approximately ¼ mile long, had been distributed along both sides of the track in single-track territory.

Several days in advance of the loading of the rail, an off-track machine, fitted with a rail threader, was used to move the welded rails close to the ends of the ties on each side of the track, to facilitate loading them onto a string of flat cars. A foreman and two laborers assisted in this operation. The work train consisted of 25 flat cars (24 equipped with rollers, and the center car equipped with anchors to hold the welded rail), and a threader car which was fitted up with a rail guide on each side of the car, securely bolted to the floor. The threader car was located at the opposite end of the train from the diesel locomotive used to propell the train, which pushed the string of flat cars under the rail.



Looking toward the end of the threader car as the pick-up train is pushed under two lengths of rails simultaneously. Note roller guides on opposite sides of the threader car; also threader truck immediately beyond car.

The threader truck, showing the adjustable rail threaders on opposite sides, in extended position, guiding two lengths of rails to the rail threader car.



Steel shoes, bolted to the ends of the long rails, guide the rail ends through the rollers on each car.

Directly ahead of the threader car was a freight car truck, equipped with a rail threader fastened to each side of the truck bolster and arranged to permit its being moved in or out to fit the position of the welded rail located at the ends of the ties. The car truck was coupled to the string of flat cars by a 39-ft rail, which served as a draw bar. A diesel locomotive crane was used to handle the car truck on and off the track and to lift the ends of the welded rails preparatory to guiding them through the rail threader and onto the threader car.

After the ends of the two welded rails, one on each side of the track, were picked up and passed through the threaders of the threader truck, and were resting on the end of the threader car, the rail ends were fitted with steel shoes to guide them into the rollers on the flat cars. The train moved at a slow speed—approximately 2 mph—until 1100 ft of the welded rails was on the flat cars. It was then necessary to connect the overhang of the rails—approximately 224 ft—to the ends of the next welded rails on the ground by means of special splice bars, and then continue moving the train until the full lengths of both ¼-mile strings were on the flat cars.

The splice bars were then removed and the next two strings of welded rail, from opposite sides of the track, were fitted with steel shoes and guided into place by shoving the flat cars under them. This process was continued until 12 strings of welded rail were on the cars, which comprised a full load. After the train was loaded, the splice bars on the last two strings of rails loaded were disconnected on the cars and the train was moved in the opposite direction, allowing the overhanging rail to be pulled away from the threader car, and back through the threader truck onto the ground. This same procedure was used when it was necessary to go into the clear for

main-line traffic. The overhanging ends of the last two rails picked up in completing the job were pulled onto the flat cars with a diesel locomotive crane. All of the 32 strings of welded rail were picked up in 4 days, averaging approximately 5 hr and 20 min loading time per day.

The personnel used to load the rail consisted of a foreman and three laborers on the cars to guide the rails through the rollers, and a foreman and eight laborers on the ground to work with the crane guiding the rail ends through the threader truck and threader car, and also to connect and disconnect the rail ends and line the rail with bars behind the threader truck to prevent rail kinks. The equipment used, other than that already mentioned, included a radio on the engine, a walkie-talkie unit used by the roadmaster, and a second walkie-talkie unit used by a member of the train crew who walked alongside the laborers guiding the rail through the rollers on the flat cars, so that movement of the train could be stopped if any difficulties arose.

The approximate cost of loading the 4 miles of rail by the method described was $1475, which covered all expenses, including work train.

Report on Assignment 5

Economics

T. A. Blair (chairman, subcommittee), Blair Blowers, W. J. Cruse, D. T. Fairies, R. J. Gammie, T. P. Polson, T. C. Shedd, Jr.

This is a progress report, submitted as information, and is based on replies to a questionnaire sent to the various railroads. Replies are tabulated in Table 1 and Table 2 of this report. Previous reports of the committee, page 1170, Vol. 54 and page 1064, Vol. 58 contain data for historic comparison and other basic data.

Of the 11 roads reporting complete cost data for rail in place, 4 roads show welded rail more expensive than jointed rail, 4 show no significant difference and 3 show welded rail less expensive than jointed rail. The average cost for welded rail in place was $40,099 per track mile and for jointed rail in place, $39,824 per track mile. Thus, the difference in average cost per mile was $275 or less than 0.7 percent. Also, it will be noted, this is slightly more than $1 per weld, assuming about 260 welds per mile of track.

Table 1, facing page 1066, Vol. 58, shows the cost of a weld to be $10.16 to $24.51, with an average cost of $14.80 for work done in the years 1948 to 1955 by the various roads; this may be compared to $5.89 to $20.00, with average cost of $12.51 shown in Table 1 of this report for work done in the years 1953 through 1958. It is evident that economies are being found in both welding and laying of welded track as the roads gain experience with continuous welded rail.

It is interesting to note that the low figure on cost per weld submitted by the Santa Fe was based on welding done in a new railway company owned plant acquired in 1958. This figure includes amortization of investment, plant upkeep and expense and all welding costs.

AVERAGES FROM TABLE 2

Annual savings on maintenance with welded rail, per mile	$568
Life of welded rail in track, years	32.3
Life of rail in jointed track, years	24.4
Time cycle, out-of-face surfacing welded track, years	9.8
Time cycle, out-of-face surfacing jointed track, years	6.8

TABLE 1

Cost Data Comparing Welded with Jointed Track - First Cost

Based on Last or Most Economical Welded Rail Job for Each Road

Railroad	Miles of Welded Trk. in Job	Weight of Rail	Year Laid	Cost Per Weld	Cost Per Mile - Welded Rail			Cost Per Mile - Jointed Track			Excess Cost Welded Track over Jointed Track in Place Per Mile
					Rail and Fittings	Labor and Unload & Lay: Work Train	Total Cost in Place	Rail and Fittings	Labor and Unload & Lay: Work Train	Total Cost in Place	
R. F. & P.	5.286	140 PS	1957	$33.89*	$50,520	-	-	$41,853	-	-	-
T. & N. O.	36.26	136	1957	12.57	36,040	$ 4,051	$40,091	37,620	$3,712	$41,332	- $1,241
S. P.	49.0	136	1958	8.00	48,795	-	-	49,680	-	-	-
U. P.	10.46	133	1948	8.21	-	7,383	-	-	4,817	-	-
Pa.	2.4	133	1958	18.00	49,542	4,000	53,542	45,014	4,200	49,214	+ 4,328
A. C. L.	3.0	132	1955	16.19	26,705	-	-	24,837	-	-	-
P. & L. E.	2.73	132	1954	20.00	30,000	-	-	26,000	-	-	-
C. R. I. & P.	5.64	132	1956	12.00	34,786	2,108	36,894	34,742	2,112	36,854	+ 40
N. Y. C.	39.7	127	1958	14.93	37,045	2,175	39,220	39,457	2,400	41,857	- 2,637
D.& R. G. W.	22.0	119	1956	9.24	28,916	1,544	30,460	26,778	2,600	29,378	+ 1,082
A. T. & S. F.	9.52	119	1958	5.89	41,832	3,657	45,489	42,723	3,959	46,682	- 1,193
S. P. & S.	5.0	115	1952	12.28	-	-	-	-	-	-	-
Soo Line	-	115	-	-	37,500	2,900	40,400	35,700	3,000	38,700	+ 1,700
N. P.	9.63	115	1958	11.12	40,541	6,579	47,120	39,236	7,606	46,842	+ 278
T. P. & W.	6.38	115	1955	10.78	30,100	2,400	32,500	30,325	2,400	32,725	- 225
Monon	8.37	115	1956	8.59	29,835	6,181	36,016	30,781	5,500	36,281	- 265
G. N.	31.1	115	1958	13.31	29,906	-	-	28,045	-	-	-
E. J. & E.	8.441	115	1953	11.69	34,092	5,262	39,354	33,504	4,700	38,204	+ 1,150
C. B. & Q.	2.06	112 TR	1951	17.84	17,506	-	-	19,958	-	-	-
Soo Line	18.16	100	1957	8.71	-	-	-	-	-	-	-
Averages				12.51**			40,099			39,824	

* Includes $18.43 weld cost and $15.46 freight.

** Does not include freight on R. F. & P.

TABLE 2

Cost Data Comparing Welded with Jointed Track - Maintenance

Based on Oldest Continuous Welded Rail Location

Railroad	Miles	Weight of Rail (Lbs.)	Year Laid	Tonnage Carried (Gross Tons)	Average Annual Cost Per Mile Maintenance: Welded Track Manhours	Welded Track Amount	Similar Jointed Track Manhours	Similar Jointed Track Amount	Excess Cost Jointed Track	Estimated Life of Rail in: Welded Track (Yrs.)	Similar Jointed Track (Yrs.)	Time Cycle Out-of-Face Surfacing: Welded Track (Yrs.)	Similar Jointed Track (Yrs.)
A. C. L.	2.41	131 RE	1947	-	-	-	-	-	-	-	-	-	-
D.& R. G. W.	6.42	133	1950	78,987,000	-	-	-	-	-	40	30	12	10
P. & L. E.	2.79	132 RE	1948	30,000,000	400	$ 900	750	$1,600	$700	28	20	10	5
S. P. & S.	5.00	115 RE	1952	-	200	500	450	1,150	650	25	20	6	4
Soo Line	10.03	10025	1953	60,000,000	-	-	-	-	-	40-45	25-30	-	-
N. P.	9.4	115	1951	17,861,000 (Per Year)	-	-	-	-	-	35	30	When required	
T. P. & W.	4.73	115	1953	4,000,000 (Per Year)	400	800	625	1,250	450	45	33	8-10	4-5
R. F. & P.	2.02	140 PS	1950	34,647,806	-	-	-	-	-	30	20	8	5
C. B. & Q.	2.06	112 TR	1951	2,484,500 (Per Year)	-	-	-	-	-	-	-	-	-
A. T. & S. F.	5.00	132	1947 (Dec.)	216,814,000	646	1,251	829	1,005	354	30	25	12	10
Monon	2.27	112	1947	3,200,000 (Per Year)	107	225	425	895	670	32	25	12	7
T. & N. O.	36.26	130	1957	16,600,000	550	1,117	1,104	1,999	882	35	26	(Est)12	8
S. P.	16.73	136	1956	53,000,000	-	-	-	-	-	-	-	-	5-8
U. P.	1.44	131	1947	406,000,000	-	2,400	-	2,510	110	19.92	19.92	12	12
Pa.	6.8	133-140-155	1956	50,000,000	-	-	-	-	-	30	18	-	-
E. J. & E.	5.966	13128	1943	-	-	-	-	-	-	30	25	9	5
N. Y. C.	1.4	127	1945	16,000,000	105	774.76	312	1,505.72	730.96	30	22	6	4
Averages						996		1,564	568	32.3	24.4	9.8	6.8

Probably almost all of the general lengthening of rail life and surfacing cycles over previous figures can be ascribed to improved maintenance practices and machinery.

With the current price of rail at about $130 per gross ton, depreciation per mile of new 132-lb rail would be at least $75 per gross ton or $15,500 per mile (207.4 gross tons). The annual investment at 5 percent to accumulate $15,500 in 24.4 years (jointed track) is $339 and for 32.3 years (welded track) is $202, giving a difference of $137 per year in favor of welded track. Since there is now no significant difference in the average costs of jointed and welded track in place, we may consider the maintenance savings to be net.

Savings based on current data from Tables 1 and 2 may be summarized as follows:

Average annual maintenance savings	$ 568
Annual savings account longer life of rail	137
Savihgs due to extended out-of-face surfacing cycle from 6.8 to 9.8 years at $7500 per mile per surfacing	338
Total annual saving per mile	$1043

There is again a large variation in the data reported by the various roads, and the statements made in the last two paragraphs on page 1065, Vol. 58, are still relevant.

Special Report on Welding Rails at or in the Vicinity of Rail Mills

Last year the president of one of the smaller (in mileage of track) midwestern railroads of the country suggested that it might be feasible for rail welding companies to set up their equipment at the different rolling mills in order to be in a position to make available to any railroads interested 78-ft rails or long strings of continuous welded rail, directly from the mills.

This suggestion has been considered by both the AREA Special Committee on Continuous Welded Rail and Committee 4—Rail, to which committees it was referred. A canvass of the railroads represented on the Committee on Continuous Welded Rail brought out the relative interest of these roads in the proposal and its advantages and disadvantages—and problems—which are summarized in the following:

Advantages

1. Many of the smaller railroads are interested in welded rail, but do not have the volume to justify the cost of establishing a welding plant on their own lines, either on a lease or purchase basis.

2. Several railroads which have not adopted the practice of using continuous welded rail are interested in securing 78-ft and 117-ft rails, which they feel might be purchased on a practical basis from a welding plant at or near a rolling mill.

3. Some railroads having their own welding set-up indicated possible interest in securing 78-ft or shorter lengths of welded rail at welding plants at or near rail mills to preclude intereference with the production of continuous welded rail at their own welding plants.

Problems and Disadvantages

The more important problems and disadvantages cited to the proposal were the following:

1. Car supply would be a major problem. If lengths in excess of 78 ft are required, cars would have to be specially equipped to handle them. This equipment is expensive,

and if the cars are not furnished by the individual purchasing roads, some pool arrangement would have to be worked out. Due to the necessity to remove or revise brake staffs and to practically eliminate slack action between cars in the handling of continuous welded rail, it is expected that present interchange rules would have to be revised if the cars are to be used in interchange service. Unless the purchasing road directly serves the welding plant site, foreign line freight charges could be expensive, and experience has shown that car delays would be excessive. Some roads have severe speed restrictions on the movement of continuous welded rail, and many insist that it be moved only in work-train service and under the supervision of representatives of the maintenance-of-way department.

2. The necessity for some standardization at such a welding plant to hold down production costs would present problems. Purchasing roads have to accept the method of welding established at any plant and, in all probability, would have to accept certain rail sections and certain lengths of continuous welded rail or shorter lengths.

3. Any lack of adequate volume at such a plant would increase the cost, and perhaps make the pooling of orders necessary.

Despite the problems and disadvantages mentioned, the committee's investigation showed that practically all of the smaller railroads contacted were interested in the proposal, and that one major railroad showed interest. On the other hand, the investigation indicated clearly that those roads which have their own welding plants, or which can justify having welding done on their own lines under a lease arrangement, feel they can take care of their requirements more cheaply and satisfactorily under these arrangements than under the proposed method.

Attitude of the Rolling Mills

To ascertain the attitude of the rail rolling mills concerning the railroad president's suggestion, the Rail committee of the AREA, through its chairman, took the matter up with the chairman of the AREA–AISI Joint Contact Committee, who, following a meeting of the American Iron and Steel Institute Technical Committee on Rails and Joint Bars called to consider the matter, advised the chairman of the Rail committee, in part, as follows:

"This welding of rail would come within the category of fabricating rather than within the scope of a rolling mill, and it developed in the discussion at our meeting that probably none of the rail manufacturers was physically equipped for this job of fabricating long rail. The conclusion, therefore, was that perhaps the best procedure toward helping some of the smaller railroads, which I understand are not in a position to provide equipment to do this work themselves, would be for them to approach individually their particular supplier of rails. In fact, I was instructed to report along this line to you . . ."

While the foregoing comments indicated clearly the final feeling of the mills toward any arrangement for the butt welding of rails at the mills, either by themselves or welding contractor, the subject was subsequently brought up at the meeting of the Joint Contact Committee held in Chicago on August 21 and 22, 1958. However, consideration of this matter was confined to brief reference to the fact that the rolling mills were not interested in rail welding at the mills, and to an announcement that one welding company had indicated its intention to set up a rail welding plant in the Chicago switching district, and had circularized a number of railroads to ascertain their probable interest in having rails but welded at this plant.

Interest of Welding Companies

There are (as of November 1958) three major companies involved in the butt welding of rails. A fourth company, recently organized, also plans to offer this type of rail welding to the railroads. In addition, a fifth company is promoting a type of weld to produce multiple lengths of rails, but since the type of weld it employs is designed to be made in track, this company is not involved in the proposal for setting up equipment for welding at or near rolling mills.

One of the three major companies referred to definitely expressed itself as not being in a position to set up and operate the type of plant in question, pointing out that it is concerned primarily with the manufacture and design of welding equipment and the sale of such, and of the materials used.

Another of these companies indicated a definite interest in the possibilities of setting up a stationary welding plant, and maintains an open mind on the matter, but cognizant of the problems inherent in such an arrangement has no present plans to establish such a plant.

The third of these companies sent a letter during the past summer to various railroads in the Middle West stating that it was seriously considering setting up a stationary welding plant in the Chicago switching district, and inquiring of those addressed as to their interest therein and as to any potential business that might be secured from them.

The fourth company previously referred to as recently organized to offer a rail butt welding service is contemplating, it is understood—under an arrangement with one of the railroads—setting up a fixed welding plant in the Chicago area to offer its service to any railroads interested.

The foregoing, which is presented as information, summarizes, as of November 1958, the situation with respect to the railroad president's suggestion.

Special Report on Field Tests on Continuous Welded Rail on Great Northern Railway

A. INTRODUCTION

1. Acknowledgement

The tests reported below were made through the cooperation of the Great Northern Railway which furnished without charge motive power, cars, track and other facilities. The various arrangements on the railway were handled both by the Engineering Department, G. V. Guerin, chief engineer, and the Mechanical Department, J. H. Heron, chief mechanical officer.

The test work was done by the staff of the Research Center under the general direction of W. M. Keller, vice president, and G. M. Magee, director of engineering research. The tests were under the direct charge of Randon Ferguson, electrical engineer, and M. F. Smucker, assistant electrical engineer. This report was prepared by Mr. Ferguson and Ralph Schinke, stress analyst, and Louis W. Leitze, engineer of track of the railway.

2. Early Tests, Instrumentation and Test Methods

The accelerated rate of installation of continuous welded rail on the railroads of the country has brought up some further need for information in some phases of its action that were not taken up in earlier testing programs. The first large scale installa-

tions of welded rail other than by street railways were on the Delaware & Hudson Railroad in the early 1930's. A mile-long stretch was also put in on the Bessemer & Lake Erie Railroad in 1936. Special tests to determine the temperature stresses and strains and track movements were started on these railroads in the summers of 1935 and 1936, respectively, and continued semi-annually until 1939. These tests were conducted by the staff of the Special Committee on Stresses in Railroad Track. A report on a half-mile installation on the Central of Georgia Railway was also made by Subcommittee 4 of Committee 5—Track, in 1939.

The special techniques and instrumentation required for these tests were worked out at that time and the results published as discussions by Dr. A. N. Talbot (Reference 1). The manner of action under temperature variations and requisite anchorage were determined as well as the holding power of the ties.

Recently the question arose as to the effect of braking applications on the longitudinal forces in the rails as possibly affecting lateral stability. Through the cooperation of the Great Northern Railway, facilities for field tests were made available during the summer of 1958. At the same time it was also decided to make readings on a "free" rail so that later changes in the longitudinal forces could be referred to an unrestrained rail basis. This "free" rail condition was obtained by loosening all anchors on a ¼-mile stretch, removing the jointed rail at the end and placing rollers at intervals between the rail base and the tie plates, as shown in Fig. 1.

Since the readings must be carried on over a period of years over wide ranges of temperatures, considerable research was done at the time of the original tests on developing proper methods, instrumentation, and information not previously available. Berry type strain gages were selected as the prime method of measuring the strains because of their portability and stability. The Berry gage is a simple dial-and-lever arrangement with a point on the end of the lever that can be inserted in a drilled hole in the specimen and indicates a change of length with reference to a point fixed with reference to the dial and inserted in another drilled hole placed at a suitable distance, in this case 8 or 10 in. It was necessary to have reference readings, and these were taken on an invar standard bar, a short section of rail and a specially designed temperature-compensated standard bar. In the compensated bar the changes in length between the gage holes was negligible over the ambient range. As part of this program it was also necessary to determine the temperature coefficients of the invar and rail steel. A further check on the method was obtained by calibrating the strain gages to obtain their temperature factor.

The rail temperatures were measured by use of a copper constantan open-point thermocouple and a portable potentiometer calibrated directly in temperature. The points reduced the volume of the couple junction to be heated and gave a reading quite quickly.

No more suitable method has been developed for this type of measurement, so the same gages and other instrumentation were used for the static part of the tests here reported. A view of the strain gage being so used is shown in Fig. 2.

The braking tests, which were, of course, under dynamic conditions, required the use of resistance-type electrical gages and electronic amplifying and recording equipment. Since the cross section of the rail is relatively large for the forces involved, the stresses due to braking action were quite small. Gages were applied to both sides of the web of the rail at the neutral axis to give increased output and to reduce the effect of the vertical and lateral flexure. A long gage length (6 in) was used to reduce

the localized effect of the direct bearing pressure stresses in giving a strain in the longitudinal direction in proportion to Poisson's ratio. This localized effect was still present directly under the wheels, but the general slope of the trace given by points between wheels indicated the general change of longitudinal stress due to braking. The values for braking force reported below were obtained in this manner. Diagrams of the test sites and gage locations are shown in Fig. 3.

B. TEST RESULTS

1. Temperature Stresses

Results of the Berry strain gage measurements at different temperatures are shown in Figs. 4 and 5. Fig. 4 shows the temperature stresses measured at the Casselton test site. This location was laid with welded rail in 1957 and was ballasted with processed gravel. The average maximum temperature stress measured on the north rail was 10,700 psi, at a rail temperature of approximately 112 deg, while the average maximum temperature stress measured on the south rail was 10,000 psi at approximately the same rail temperature.

Fig. 5 shows the temperature stresses measured at the Nolan test site. This section of track was laid with welded rail in 1957 on crushed rock ballast from Granite Falls. Slightly higher rail temperatures were recorded at this location. The average maximum temperature stresses on the north rail was approximately 13,000 psi at a rail temperature of approximately 126 deg. For the south rail the average maximum stress was approximately 13,300 psi. It should be noted that there is less drop-off of stress on the end sections at the Nolan site than at the Casselton site. This shows that there is probably less restraint at the end sections at Casselton.

2. Braking Tests

The results of the braking tests are shown in Figs. 6 and 7. The results obtained from these tests indicated very little longitudinal compressive stress was developed ahead of a 5000 ton train under full service application of brakes. The maximum compressive force at Casselton was 12,800 lb., which is equivalent to a stress of 1140 psi. The maximum compressive force recorded at Nolan ahead of the train was 16,200 lb., which is equivalent to a stress of 1440 psi. Compressive forces under the train were slightly higher, the maximum being 19,400 lb., which is equivalent to a stress of 1380 psi. The tensile stresses which occurred after the train had passed were very small, not exceeding 1110 psi.

3. Jackknifing Tests

Longitudinal forces were also measured in the rail during the jackknifing runs. These results are shown in Fig. 8. The maximum compression behind the train was 16,500 lb force. The maximum tension force occurred under the train between the cars and the first pushing unit and was 35,100 lb., which is equivalent to 3120 psi stress.

4. Bending Stresses

The bending stress on the bottom surface of the base of the rail was measured at Nolan on the braking and jackknifing runs. These results are shown in Fig. 9. On the braking runs the maximum stress was 17,700 psi. For the jackknifing runs the maximum stress was 27,300 psi. It should be noted that the jackknifing stresses were considerably lower on the units which had either the National Malleable M380 coupler

alinement control or the GN modified coupler alinement control, the maximum stress recorded with the M380 being 23,100 psi. The maximum stress recorded with the GN modified was 21,300 psi.

C. CONCLUSIONS

It appears from these measurements that the maximum stress developed in the rail due to temperature, bending and braking of the train will be well below the yield strength of the rail steel. Its average yield strength is approximately 70,000 psi. The temperature stress measurements show the maximum compressive stress averages 13,300 psi at a rail temperature of 126 deg. This occurred with the rail temperature approximately 65 deg above the laying temperature. With the rail at 40 deg below zero, it may, therefore, be anticipated that the temperature stress would be approximately 20,000 psi tension. Adding to this a bending stress in the base of the rail of 27,300 psi and a longitudinal tensile stress of 3,120 psi developed in the rail under jackknifing locomotives, gives a maximum combined tensile stress of 50,400 psi, which is well within the yield strength of 70,000 psi previously stated. Arrangements have been made to measure the anticipated tension at low temperatures by taking the Berry strain gage readings at below zero temperatures this winter.

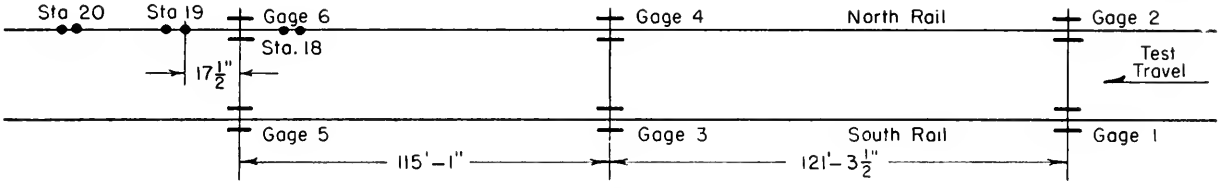
There are no experimental data available on the amount of compressive forces necessary to buckle a section of track. However, it appears that the buckling forces that were measured due to braking were very nominal. Some theoretical studies of this buckling force problem have been published (References 2 and 3).

D. REFERENCES

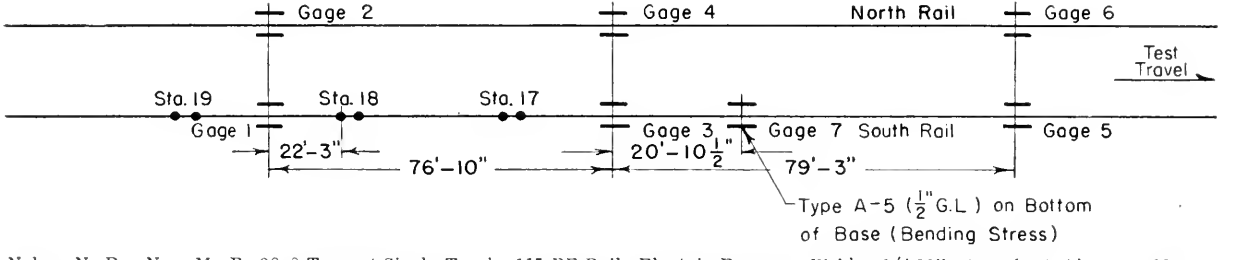
1. Discussions by A. N. Talbot, Procedings, AREA, Vol. 32, page 954; Vol. 38, page 674; Vol. 39, page 857; Vol. 40, page 549; Vol. 41, page 659.
2. R. Levi, "Influence of Transverse Rigidity of the Track on the Risk of Deformation Due to Longitudinal Compression", Bulletin, International Railway Congress Association (English Edition), July 1958, page 1115.
3. M. Numata, "Buckling Strength of Railway Track (Report 1)" (Japanese), Journal of Railway Engineering Research, August 15, 1957, page 343.

Fig. 1—Roller placed under freed rail to eliminate longitudinal restraint for temperature stress measurements.

Fig. 2—Berry strain gage for measuring temperature strains.



Casselton, N. D., Near M. P. 50.5, Tangent Single Track, 115 RE Rail, Electric Pressure Welds, 1/4 Mile Length, Laid Sept. 1957, Processed Gravel Ballast, Gautier Rail Anchors, Anchored Both Ways On Every Tie 200 to 300 Ft. From Ends and Then Every Third Tie.



Nolan, N. D., Near M. P. 38.8, Tangent Single Track, 115 RE Rail, Electric Pressure Welds, 1/4 Mile Length, Laid Sept. 1957, Crushed Rock Ballast, Fair Rail Anchors, Anchored Both Ways on Every Tie 200 to 300 Ft. From Ends and Then Every Third Tie.

All Gage Pairs SR-4 Type A-9 (6 in. Gage Length) On Web Along Neutral Axis Except as Noted

Fig. 3 – Track Data and Gage Locations Great Northern Railway

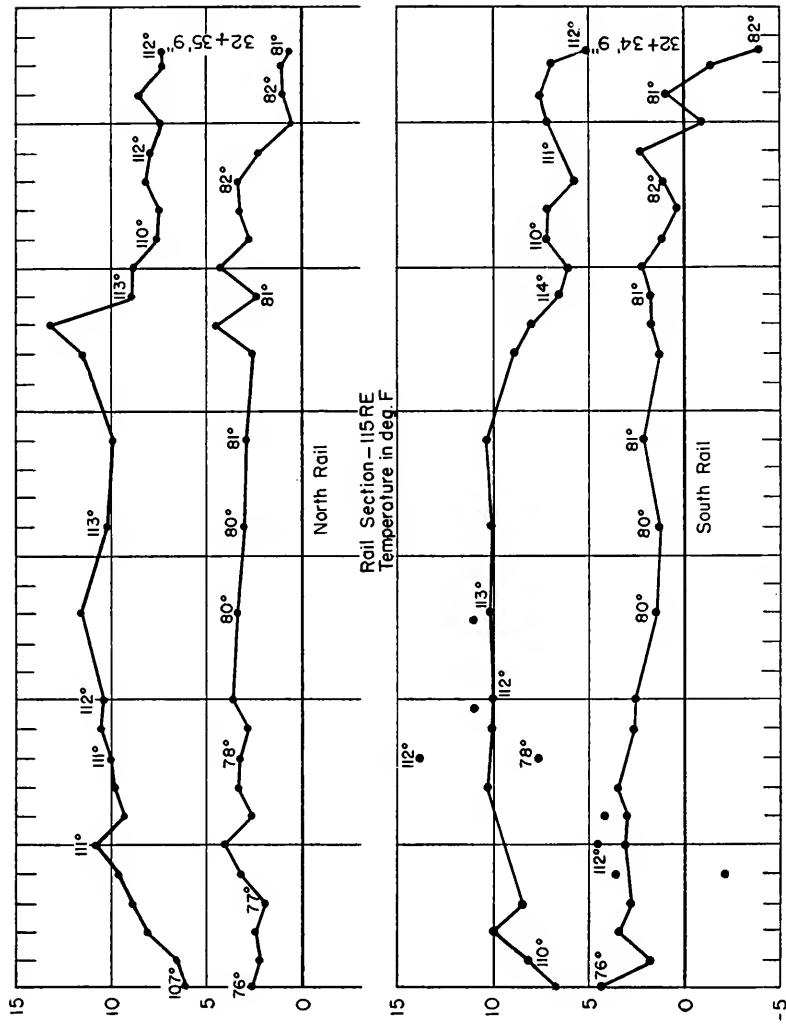


Fig. 4-Temperature Stresses in $\frac{1}{4}$ Mile Length of Rail, Great Nor Ry., Casselton, N.D.

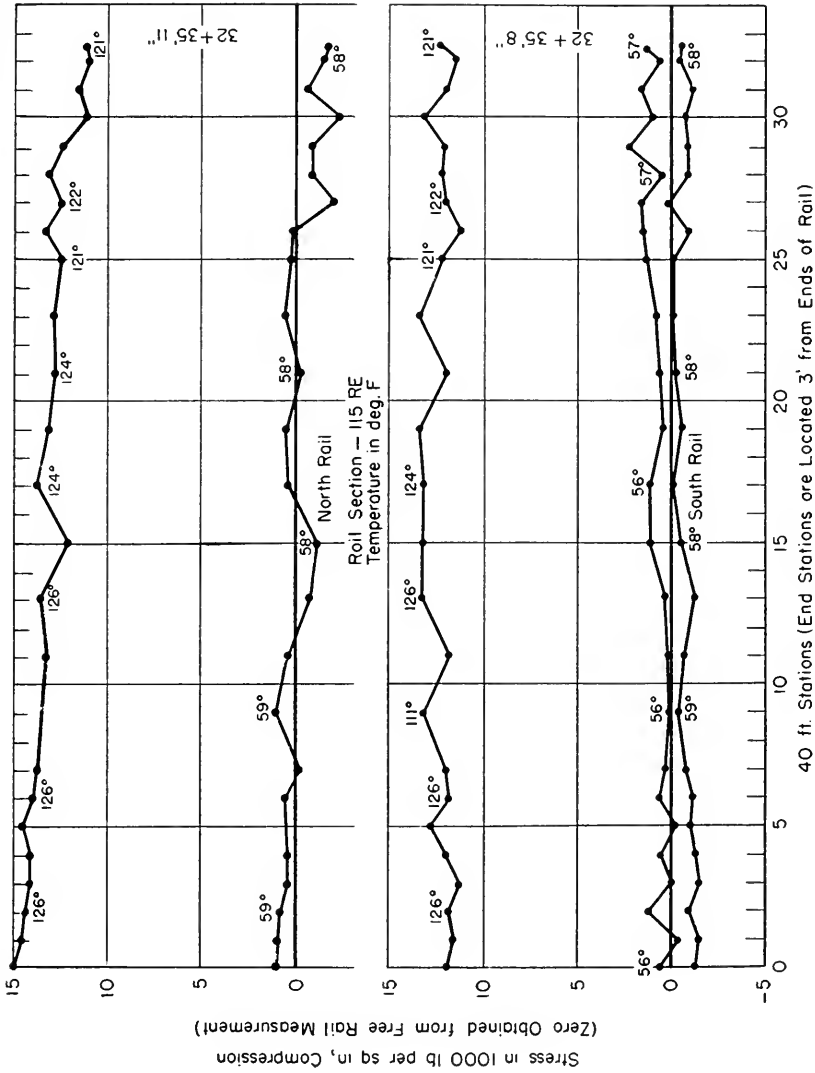
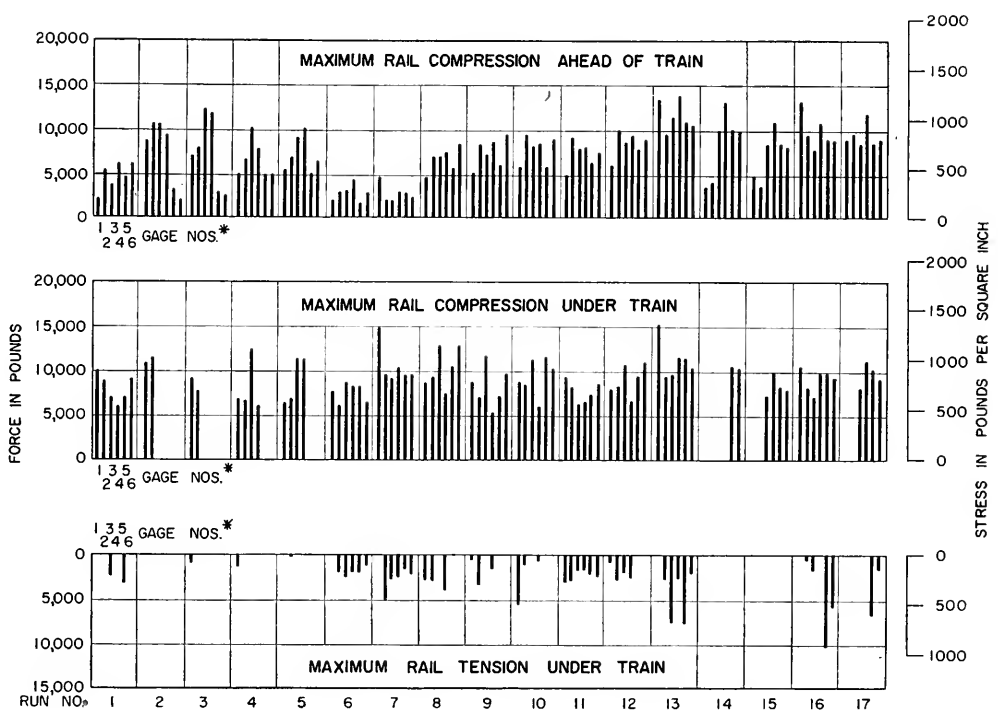
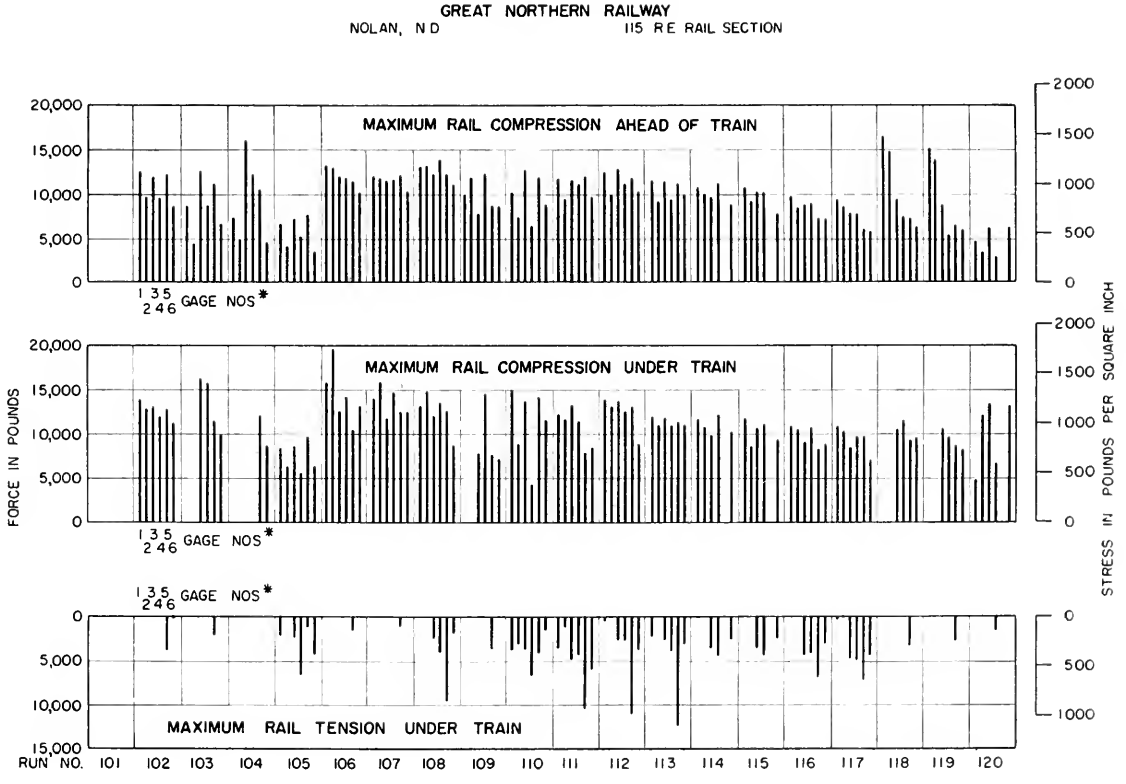


Fig 5-Temperature Stresses in $\frac{1}{4}$ Mile Length of Rail, Great Nor Ry, Nolan, N. D.



*GAGE NOS APPLY TO EACH RUN, ODD NUMBERS ARE SOUTH RAIL AND EVEN NUMBERS ARE NORTH RAIL, SEE FIG. 3 FOR GAGE LOCATIONS

FIG. 6 LONGITUDINAL RAIL STRESSES, BRAKING RUNS, FIVE DIESEL UNITS AHEAD OF 56 CARS OF 5100 TONS



*GAGE NOS APPLY TO EACH RUN, ODD NUMBERS ARE SOUTH RAIL AND EVEN NUMBERS ARE NORTH RAIL, SEE FIG. 3 FOR GAGE LOCATIONS

FIG. 7 LONGITUDINAL RAIL STRESSES, BRAKING RUNS, FOUR DIESEL UNITS AHEAD OF 30 CARS OF 2500 TONS

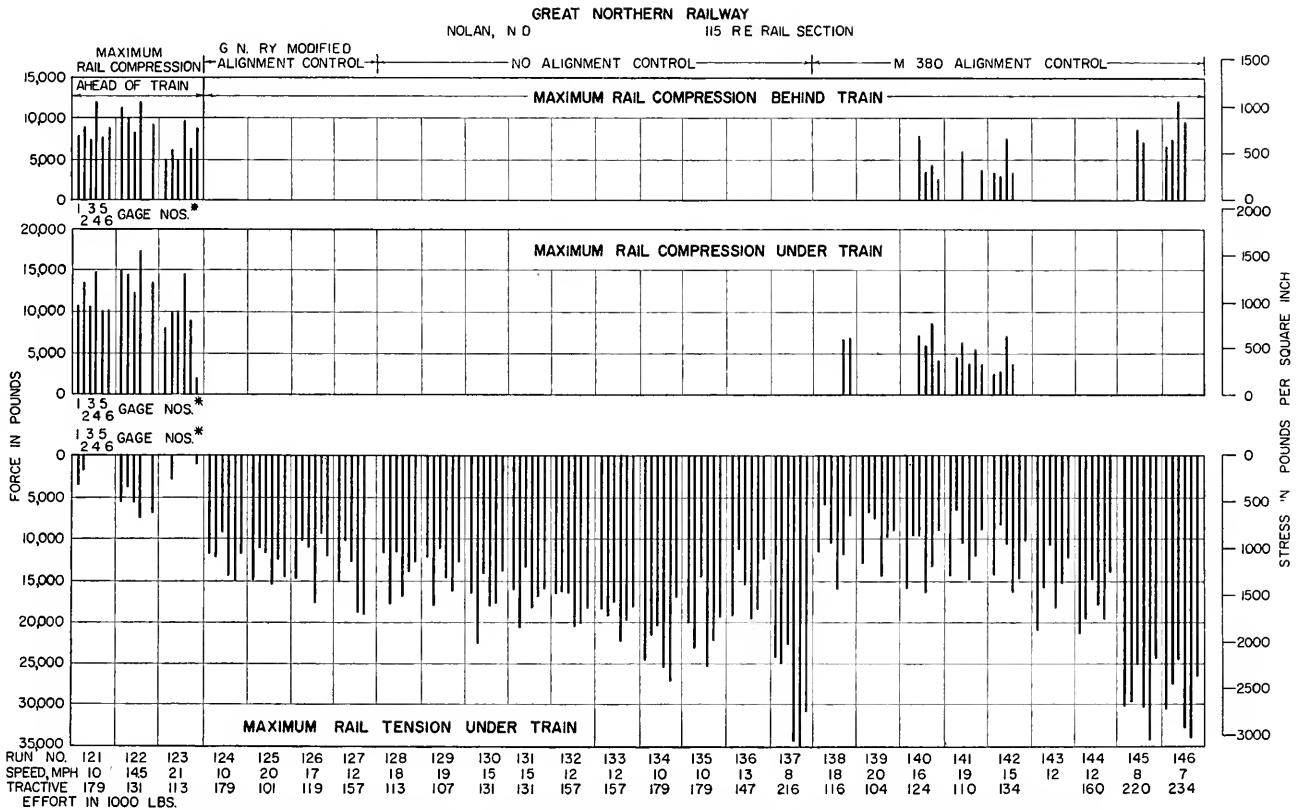
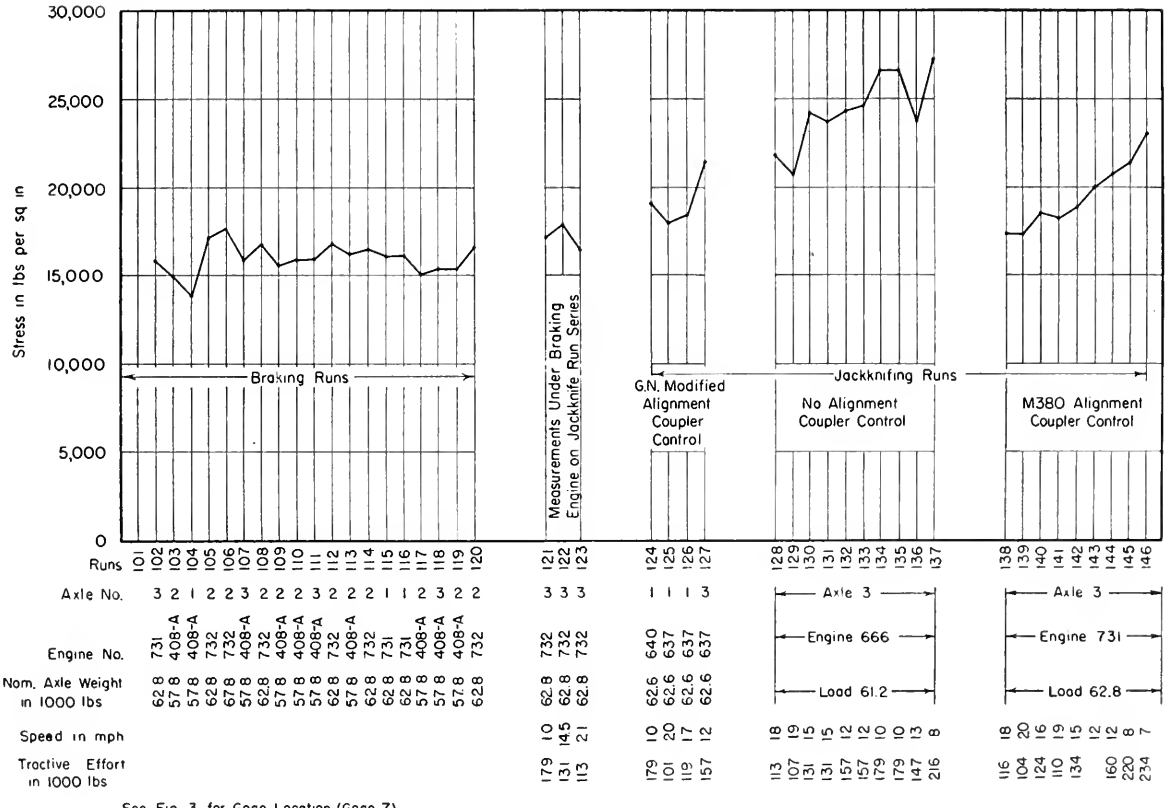


FIG. 8 LONGITUDINAL RAIL STRESSES, JACKKNIFING RUNS, FOUR DIESEL UNITS PUSHING 30 CARS OF 2500 TONS AND FOUR UNITS IN DYNAMIC BRAKING



See Fig 3 for Gage Location (Gage 7)

Fig 9-Maximum Vertical Bending Stress in Base of Rail, 115 RE Section, Great Nor. Ry., Nolan, N D

Report of Committee 1—Roadway and Ballast

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C. E. WHITMORE, JR.
Committee.

(E) Member Emeritus.
* Died November 6, 1958.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report (See reports on Assignments 4, 8 and 10)

2. Physical properties of earth materials:

   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.
   (b) Structural foundation beds, collaborating with Committees 6 and 8.
   Progress in study, but no report.

3. Natural waterways: Prevention of erosion.

   Progress report, presented as information ..... page 657

4. Culverts:

   (a) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor.
   Final report, submitted for adoption and publication in the Manual .... page 665

5. Specifications for pipe lines for conveying flammable and nonflammable substances.
   Progress report, presented as information ..... page 668

6. Roadway: Foundation and protection:

(a) Roadbed stabilization.
Report on soil engineering problems on the Quebec, North Shore & Labrador Railroad, presented as information ..... page 668
(b) Slope protection by use of additives.
Progress in study, but no report.

7. Tunnels:

(a) Ventilation; changes necessary for operation of diesel power.
(b) Clearance; methods used to increase, collaborating with Committee 28.
Progress in study, but no report.

8. Fences

Progress report, with recommendations for revisions to Specifications for Right-of-Way Fences ..... page 688

9. Roadway signs:

(a) Reflectorized and luminous roadway signs, collaborating with Committees 5 and 9, and with the Signal Section AAR.
Progress report, presented as information ..... page 693
(b) Develop standard close clearance warning sign, collaborating with Committee 28.
Progress in study, but no report.

10. Ballast:

Recommendations for revisions to Specifications for Prepared Stone, Slag and Gravel Ballast ..... page 710
(a) Tests.
Progress report, presented as information ..... page 711
(c) Special types of ballast.
Progress report, presented as information ..... page 712
(d) Specifications for sub-ballast.
Progress in study, but no report.

11. Chemical control of vegetation, collaborating with Signal Section and Communications Section, AAR.

Progress report, presented as information ..... page 714
Part 1—Vegetation Control on Iowa Roadbeds ..... page 715
Part 2—Railroad Weed Control, North Carolina State College ..... page 723
Part 3—Chemical Control of Vegetation—1958 AAR Report ..... page 732
Part 4—Cost of Developing a New Herbicide ..... page 782

THE COMMITTEE ON ROADWAY AND BALLAST,
G. B. HARRIS, *Chairman.*

AREA Bulletin 549, February 1959.

MEMOIR

Lloyd Dewaine Shelkey

Lloyd Dewaine Shelkey, assistant engineer, Bessemer & Lake Erie Railroad Company, Greenville, Pa., was instantly killed in an automobile accident, November 6, 1958, while returning to Greenville from an assignment at the south end of the railroad. He is survived by his wife Dorothy Melvin Shelkey; his son, Larry D. Shelkey of Columbus, Ohio; his step-son, William Broadbent of Greenville; his father William C. Shelkey, and sister, Mrs. William Chalfant, both of Uniontown, Pa.

Mr. Shelkey was born December 3, 1911, in Perry Township, Westmoreland County, Pennsylvania, the son of William C. and Irene Livingston Shelkey. He received his education in the Uniontown public schools and the University of Pittsburgh, graduating in 1933 with a B.S. degree in Civil Engineering.

Mr. Shelkey entered railroad service in 1934 with the engineering corps, Pennsylvania Railroad and in 1936 was promoted to assistant supervisor track. On May 7, 1941, he joined the service of the Bessemer & Lake Erie as assistant supervisor track, subsequently being promoted successively to supervisor track, office assistant to chief engineer and, on June 1, 1955, to assistant engineer, which position he held at the time of his death.

He was a member of the First Methodist Church of Greenville and held membership in the B.P.O.E., Railway Club of Greenville, and Pittsburgh Railway Club.

Mr. Shelkey became a member of the American Railway Engineering Association in 1949 and of Committee 1 in the same year. His interest in and his continuous and generous contributions to the work of the committee, as well as his humor and friendliness among its members, will long be remembered. The Association and Committee 1 have lost a valuable and outstanding member and those with whom he was closely associated have lost a sincere friend.

Report on Assignment 3

Natural Waterways: Prevention of Erosion

F. R. Naylor (chairman, subcommittee), R. A. Anderson, G. W. Becker, B. H. Crosland, J. K. Fisher, F. H. McGuigan, J. A. Noble, J. M. Thomson.

In 1955, your committee presented, as information, a report on the prevention of bank erosion in natural waterways of the alluvial type by the use of steel jetties (Proceedings, Vol. 56, 1955, pages 679 to 687, incl.) In 1957 a supplemental report was submitted covering various other types of stream-bed and bank-protection installations (Proceedings, Vol. 58, 1957, pages 717 to 734, incl.).

The following report covers an additional method for preventing erosion, the results obtained under flood conditions from previously described installations, and the effects of the floods on the various installations. It is presented as information.

Gabions

Gabion structures have been widely used in various European countries, Canada, and to a lesser extent in the United States for preventing erosion. They are now readily available for use in this country but are protected by patent rights.

Gabions may be described as large wire-mesh boxes made from high-grade steel wire specially coated to resist corrosion from fresh, polluted or salt water, or weathering, in permanent structures. They are filled with small rocks or stones to insure maximum permeability and flexibility. In river, torrent and stream works, and lake or seashore works, small river boulders, waste rocks, or quarry stones from 5 to 8 in. in size are the most suitable. Smaller sizes than 5 in can be used advantageously for the core of the structure but the rocks in contact with the external mesh must be 5 in or over.

Gabion structures are designed to form stepped or vertical walls, permeable dikes and dams, groins, jetties, weirs, breakwaters, sea walls and retaining walls of any height and thickness and are used for protecting structures or areas endangered by erosion. In constructing gabions, licensor's directions and specifications must be carefully followed.

In filling gabions only clean rocks must be deposited in the gabions. To facilitate this operation devices such as rock forks, scoops and buckets in the form of sieves can be used advantageously. The deposited rocks must be arranged in a manner to prevent undue voids.

An outstanding advantage of gabion structures over conventional rigid or semi-rigid structures is their flexibility when subjected to pressure or when the base course subsides through scouring of its bed. This flexibility prevents loss of static and protective efficiency and permits their adaptation during adverse conditions until they achieve the desired stability. Gabion structures must never be grouted to form a solid mass. (Typical gabion structures are shown in Figs. 1 through 4).

The purpose of the platform or base course, which is the most important feature in river, torrent, stream bank and seashore works, is to counteract the undercutting action of the water. This is effected by the folding down of the platform of its own accord when bed erosion occurs.

A gabion structure is a fixed mass, as the gabions are tied to each other, and because of its weight, it has great static resistance. It is permeable; water flows through the structure easily without under pressure or counter pressure and without damage to the structure. It is always possible to increase or reduce the size of the structure.

Gabion structures are designed to:

a. Withstand and control violent currents and hydraulic pressures in torrents, small streams and rivers.
b. Dissipate and absorb wave energy on sea and lake shores.
c. Expel water from porous soil, functioning as strong retaining walls to prevent land slides and to reinforce unstable slopes and banks.
d. Remain intact when placed on mud, silt, sand and soil subject to frost, heavy rains or other situations where there is lack of soil bearing strength.

Gabions have great capacity to expand without bursting. If one or more links should break, the gabion remains integral and can be easily repaired. If found desirable gabion structures can readily be enlarged or altered. The gabion method is very simple, and common laborers after brief experience learn the technique quickly.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

When an attractive appearance is desired, especially for structures built on highways, public parks and other public places provided they are not attacked by waves or currents), the facade can be made with square concrete blocks, old bricks, square stones or granite of a minimum thickness. The quantity of this material required is only the very small portion needed to cover the external surface of the structure. Random waste rocks or river boulders must be used for the mass filling of the structures core.

To insure the maximum permeability and flexibility, it is obvious that a square facade should be avoided for structures exposed to water attack in torrents, streams, rivers, lakes, canals, and ocean shores. In these cases, if an attractive appearance is desired, it is preferable to rearrange the deposited rocks by hand for the front face.

Gabions can be used for emergency defense works during floods. They are sunk, already filled, in the dangerous areas.

Steel Jetties

The report published in Vol. 56 deals with installations of steel jetties and their function in preventing erosion by causing a deposition of water-borne materials.

Any failure of jetties, especially those having a history of long, satisfactory service, can be of great concern to those responsible for their installation and performance. One type of failure has been noted where silt built up by the jetties through the years is again picked up by the river, leaving jetty units uncovered and isolated. Where such failures are located downstream from a flood-control reservoir, the de-silting action of the storage facilities may become suspect.

A jetty's ability to accrete new fill is dependent on its ability to reduce river velocities to a point where silt-laden water will drop a portion of its load. It appears reasonable to assume that water which has already been de-silted while passing through a reservoir will contain less material to be dropped by the action of a jetty located downstream.

In addition to the reduction of the silt-dropping characteristics of jetties performing in cleared water below a reservoir, a secondary action may occur to further reduce the effectiveness of these units, based on the tendency of a stream to maintain a condition of equilibrium. Thus, with some of its silt removed at the reservoir, an acceleration in erosion of streambed and banks may be expected below the flood-control structure. It is reasonable to believe, then, that accretion formerly deposited by the installation of jetties will again be picked up by the river, leaving them uncovered and exposed.

It is expected that further study will be made to determine more fully the action of clear water on steel jetty layouts, and the probable effect of having flood-control reservoirs located upstream from them.

Pile Dikes, Fascine Boxes and Revetments

The report published in the Proceedings, Vol. 58, describes timber pile dikes, fascine boxes and revetments. Installations of each type have been made at various locations on the Red River in Louisiana during the past several years.

During May and June 1957 and again during May 1958, this river, the banks of which are subject to rapid erosion, was in flood with very high gage readings. After these floods receded and water had reached normal stage, inspections were made to determine the effect of these floods on the various bank protection installations and the banks they were installed to protect. Locations are referred to by number.

No. 1, a pile dike installation (Vol. 58, Fig. 10) protecting a long, easy, bend was in excellent condition and has functioned as planned in protecting this bank against

erosion. There has been no loss of bank since these dikes were driven many years ago.

No. 2, a fascine box installation (Vol. 58, Fig. 3) protecting an easy bend in the river, limited bank erosion to a minimum. The boxes were damaged by a heavy flow of drift, and expensive repairs must be made to maintain their efficiency. This installation, which now protects approximately one mile of bank, was begun in 1934. At various times during succeeding years, the boxes have been renewed and the bank coverage extended. Up to the present time the total cost for installation and maintenance is $236,400, or slightly less than $50 per foot of bank protected.

No. 3, another fascine box installation (Vol. 58, Fig. 4) protecting a "horse-shoe" bend, has functioned as planned. There was no bank erosion and very little damage to fascines by drift. The additional deposit of sand and growth of vegetation in this bend indicates desired stabilization.

No. 4, a pile dike installation (Vol. 58, Fig. 8) was seriously damaged by drift and scour. The upper trail dike and dike number one remained intact, building substantial bars. The remaining dikes were badly damaged or completely destroyed, requiring their replacement by new dikes, which has been done. The loss of bank where dikes were destroyed was small, indicating that they afforded some protection against erosion. A natural cut-off in the river channel has occurred a short distance upstream from these dikes. This has resulted in a change in current direction, moving the point of attack and causing much loss of bank downstream from the dike-protected bank. Fig. 5 shows traces of the old and the replacement dikes.

No. 5, another pile dike installation was damaged, requiring reinforcement and extention, but gave adequate protection to the bend. Between dikes, along what had been an eroding bank, heavy deposits of sand have reinforced the bank slope, affording proper stabilization. Fig. 6 shows a heavy deposit of sand ahead of and behind the new trail dike. Traces of the old dike appear above the new. Fig. 7 shows the build up between dikes along what had been an eroding bank.

No. 6, a long bend protected by revetment, pile dikes and fascines (Vol. 58, Fig. 13) had negligible loss of bank as a result of the floods, although the long trail dike was severely damaged and has been repaired and extended. The portion of bend protected by revetment has also been extended to prevent undercutting. Fig. 8 shows the new and extended trail dike. Fig. 9 shows the upper end of the new trail dike and, above it, sections of bank protected by revetment.

No. 7, a pile dike installation protecting a short, sharp bend, was completely destroyed, with bank erosion approximating 200 ft. This installation has been replaced with additional dikes added in an effort to prevent further erosion and loss of valuable land, including a paved road.

Inspections made show that, due to various factors, particularly change in current direction, pile dike installations do not always function as planned.

The failures occurring in the various types of installations made to prevent erosion, the mounting costs incurred in making and maintaining them and changing conditions resulting from the construction of dams and improvement of waterways, justifies a further investigation and report on this assignments. The committee recommends that it be continued.

Fig. 5.

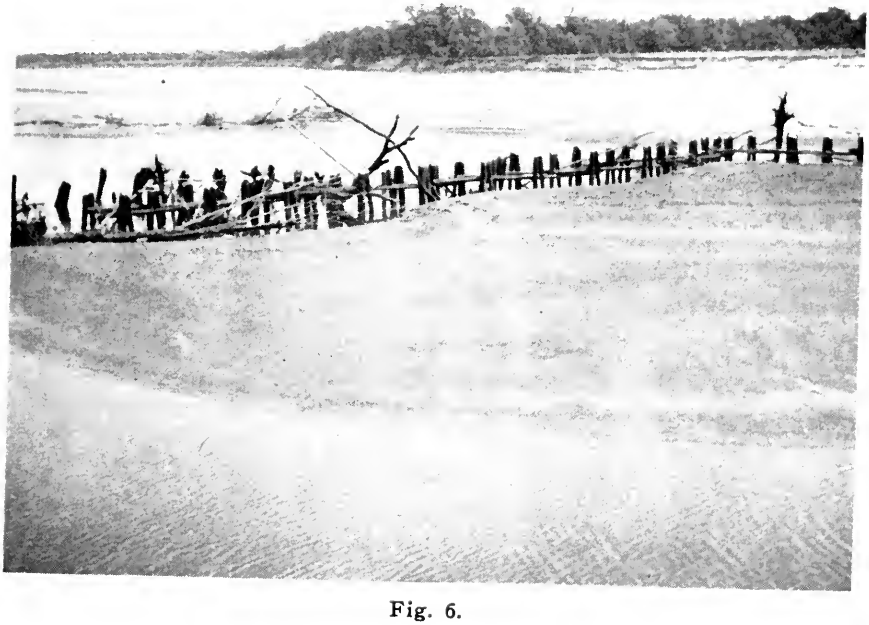

Fig. 6.

Fig. 7.

Fig. 8.

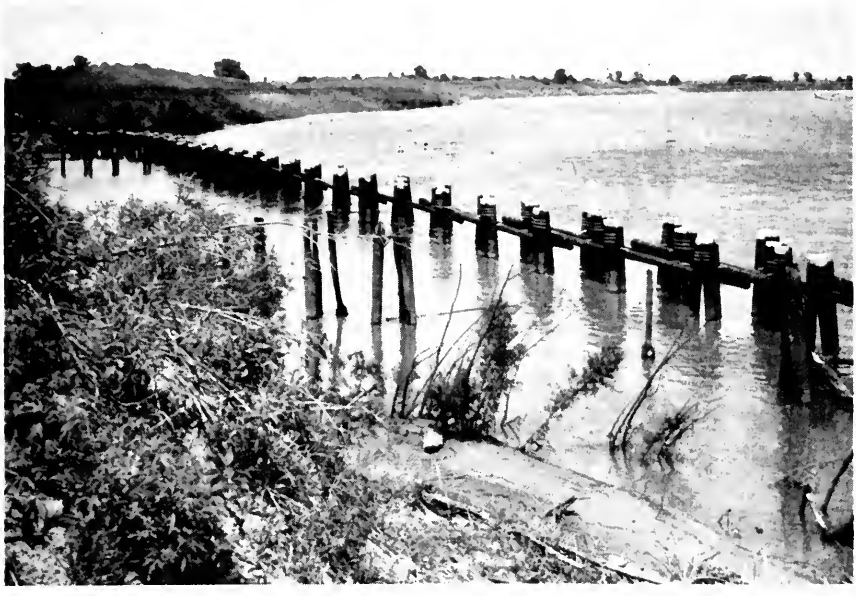

Fig. 9.

Report on Assignment 4 (a)

Conditions Requiring Headwalls, Wingwalls, Inverts and Aprons, And Requisites Therefor

G. D. Mayor (chairman, subcommittee), W. T. Adams, D. W. Blair, T. F. deCapiteau, C. W. Reeve, G. E. Shaw, C. E. Whitmore, Jr.

Your committee submits the following report with the recommendation that it be adopted and published in the Manual at the end of Part 4—Culverts, Chapter 1. It also recommends that the subject be discontinued.

CONDITIONS REQUIRING HEADWALLS, WINGWALLS, INVERTS AND APRONS AND REQUISITES THEREFOR

A. INTRODUCTION

The design and installation of each culvert must be considered as an individual engineering and economic problem. The engineer must determine the basic requirements of type, strength, capacity, service, location, alinement, grade, and other factors pertinent to the efficient function and economic installation and maintenace of the culvert.

In addition, he must decide if the physical conditions, both present and during the projected life of the culvert, warrant the inclusion of headwalls, wingwalls, inverts, and aprons as part of the installation.

Occasionally, aesthetic considerations may require the use of these appurtenances

within built-up communities or in prominent locations where a pleasing appearance is necessary, but normally this is not a major consideration. In most cases it is more expedient to use other and less expensive methods to avoid all or part of these end finishes. For example, except where limited right-of-way makes it necessary to provide headwalls and wingwalls, it is usually more economical to extend pipe culverts. Box and arch culverts, especially when of large capacity, present a somewhat different problem. Again, however, the cost of installation must be carefully compared with other solutions, such as grouted rip-rap, sheet piling, etc., which might provide adequate protection at less cost.

B. HEADWALLS

1. Factors and Conditions

The following factors and conditions may require the use of headwalls:

a. Angle of repose, type, height, and stability of fill material.
b. Inability to hold good vegetation on slopes.
c. Prevention of washouts.
d. Reduction in cost of culvert by shortening installations.
e. Right-of-way limitations.
f. Longitudinal stability for short pipe sections to prevent pulling apart. (Only where adequate foundation is available).
g. Improvement of appearance.
h. Prevention of undercutting, scour, burrowing and seepage.

2. Design

Headwalls should be designed by the engineering department, usually the bridge engineers' office, and standard design procedures should be followed.

Economic considerations, based primarily on the required height of the headwall, will determine whether a gravity or reinforced concrete type of structure should be used. The design should provide for all loads, including surcharge and impact, and particular attention should be given to the method used to determine earth thrust. It is very important that the actual soil conditions closely approximate the theoretical conditions assumed in the design. If not, only design methods which through past experience are known to give satisfactory results should be used.

The headwall should have adequate integral strength, and should be proportioned to prevent sliding or overturning from excessive soil pressures. It should be self supporting, and every effort should be made to design against settling. In the case of pipe culverts, this point cannot be overemphasized, as the effectiveness of a carefully located and bedded pipe can be nullified by the settling of an inadequately supported headwall.

Cut-off walls, where required, should be of sufficient depth to eliminate undercutting.

C. WINGWALLS

1. Factors and Conditions

The following factors and conditions may require the use of wingwalls:

a. Angle of repose, type, height and stability of fill material.
b. Height of culvert.
c. Direction, width and gradient of stream channel.

d. Amount and velocity of run-off.
e. Need for increased hydraulic efficiency.
f. Prevention of scour during periods of maximum run-off.

2. Design

Structurally, the same principles govern the design of wingwalls as of headwalls. Gravity-type construction is economically desirable for walls of limited height. The walls should be self supporting, and a well reinforced apron, where required, will materially assist toward this end. Footing to meet the most adverse conditions encountered should be used, and should be proportioned to provide uniform bearing pressure over the full length of the wingwall. This will assist in preventing separation between the body of the culvert and the wings.

Perpendicular, oblique, or parallel wingwalls, or a combination thereof, should be used, depending on the physical and hydraulic conditions involved. Careful field engineering is necessary to ascertain that the wingwalls, if skewed, will not change stream direction or encourage turbulence during periods of heavy run-off.

The height of the culvert and incidence of high water will, to a great extent, govern the length of the wings. Oblique walls are usually tapered from the top of the headwall to a height of approximately 2 ft. Parallel walls may taper their full length to the footing.

D. INVERTS AND APRONS

1. Factors and Conditions

The following factors and conditions may require the installation of inverts and aprons:

a. Prevention of erosion and scour; dispersion of flow.
b. Resistance to corrosive and abrasive materials carried by a stream.
c. Increased hydraulic efficiency.
d. Use of culvert as cattle underpass or other purpose, in addition to drainage.

2. Design

Inverts and aprons should be carefully designed and reinforced, and should be built to carry and control the hydraulic traffic.

Aprons should be long enough to carry the water well past the toe line at embankments, and should be so designed as to avoid turbulence and eddies. Cut-off walls should be used to prevent undercutting, where necessary.

Inverts and aprons of culverts handling abrasive and corrosive waters require special care. Those carrying large quantities of abrasive material can be readily protected by properly designed and bonded paving. Mine water, however, particularly from coal, copper and zinc mines, attacks concrete. Water passing through sulfur-bearing rocks or soils and alkaline water have a similar deteriorating effect. Asphaltic or other nonmetalic paving should be considered where corrosive rather than abrasive atttack is the governing factor.

Paving of inverts of culverts to be used as a cattle underpass should be designed to provide reasonably secure footing. Brushed concrete provides an excellent invert if the fall is not excessive. Where this condition exists cleats may be formed in the concrete to provide additional footing. Bituminous material may also be used as a paving, although small sharp-hooved livestock will soon cut this type of paving badly, and cause it to deteriorate quickly.

Report on Assignment 5

Specifications for Pipelines for Conveying Flammable and Non-Flammable Substances

K. W. Schoeneberg (chairman, subcommittee), W. T. Adams, L. H. Bond, H. W. Clarke, T. F. de Capiteau, J. W. Purdy, C. W. Reeve, R. W. Scott, A. J. Wegmann.

Your committee submits as information a progress report on its activities and studies relative to pipeline crossings under railroads and longitudinal or parallel occupancy by pipelines on railroad right-of-way.

As reported at the 1958 convention, the Pipeline committee of the Construction Division, American Society of Civil Engineers, appointed a special committee to make a study of pipeline crossings of railroads and highways with the view of preparing a specification that would be acceptable to all interests concerned. The AREA is represented on this committee by three members of Committee 1 and one member of Committee 15.

Several meetings have been held and committee task groups were formed, and much progress has been made in the formulation of primary specifications of design, construction and maintenance of pipeline crossings under railroads and highways. Our AREA representatives are working diligently with these people to see there is no change that would adversely affect the railroads.

Study is also being made of the present specifications as printed in the Manual with the view in mind that certain revisions should be made.

Progress is also being made by your committee in its studies pertaining to the ever-growing problem of longitudinal or parallel occupancy of pipelines on railroad right-of-way.

Report on Assignment 6

Roadway: Formation and Protection

(a) Roadbed Stabilization
(b) Slope Protection by Use of Additives

L. D. Shelkey (chairman, subcommittee), F. N. Beighley, T. W. Creighton, B. H. Crosland, H. O. Ireland, A. J. Pacelli, G. S. Sowers, C. E. Stoecker.

Your committee reports this year on Assignment (a) only. The report presented as information, covers "Soil Engineering Problems" on the Quebec, North Shore & Labrador Railway. It was prepared by Professor K. B. Woods, head, School of Civil Engineering, Purdue University; R. W. J. Pryer, soils engineer, Quebec, North Shore & Labrador Railway; and W. J. Eden, Division of Building Research, National Research Council, Canada.

Soil Engineering Problems on the Quebec North Shore & Labrador Railway

By K. B. Woods,* R. W. J. Pryer,** W. J. Eden***

A. SYNOPSIS

The construction of a 360-mile railroad to reach the iron-ore deposits in Quebec–Labrador in terrain virtually unknown could be expected to raise serious problems with respect to soil conditions. The climate of the region imposed another set of difficulties because the winters are severe and the short summer season is cool with frequent rainfall. This paper points out the difficulties that were caused by soil conditions and sets forth some of the measures taken to remedy the situation.

Slope stability in banded clays was a serious problem in the first 30 miles. Because of the climate, frost action was a major consideration throughout the length of the line. Construction problems were mainly caused by loose, saturated soils with very poor natural drainage, and frequent rainfall in the summer months.

B. INTRODUCTION

Few engineering projects in recent years have matched the scale of the iron-ore development in Quebec–Labrador. A major phase of this undertaking was the construction of the Quebec North Shore & Labrador Railway between the rich iron-ore deposits of the Schefferville area and the tidewater docks at Sept Iles. This paper summarizes some of the soil engineering problems encountered in this undertaking and discusses methods used to solve the difficulties encountered.

The railway, a single-track line, is based at tidewater 1 mile east of the town of Sept Iles on the north shore of the Gulf of St. Lawrence, and some 484 miles northeast of Montreal. Schefferville (El. 1700), the northern terminus, is almost due north of Sept Iles, a distance of 358 miles by rail. The terrain traversed by the railway (Fig. 1) may be described generally as the Laurentian Plateau of the Canadian Shield, but a number of different geological and soil formations are encountered, each one raising problems peculiar to the location.

Reconnaissance and aerial surveys were undertaken in 1945 and 1946 (1)† and preliminary lines run during the following two years. In 1949, optimum train lengths, weights and speeds having been established, final location surveys were begun. Construction commenced in late 1950 (2) and track laying was completed in February 1954. A total of 21 million cu yd of excavation was required, 6 million cu yd being involved in the construction of haulage roads and 11 intermediate airstrips between those at Sept Iles and Schefferville.

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*** Division of Building Research, National Research Council, Canada.
† Numbers in parenthesis refer to references at end of report.

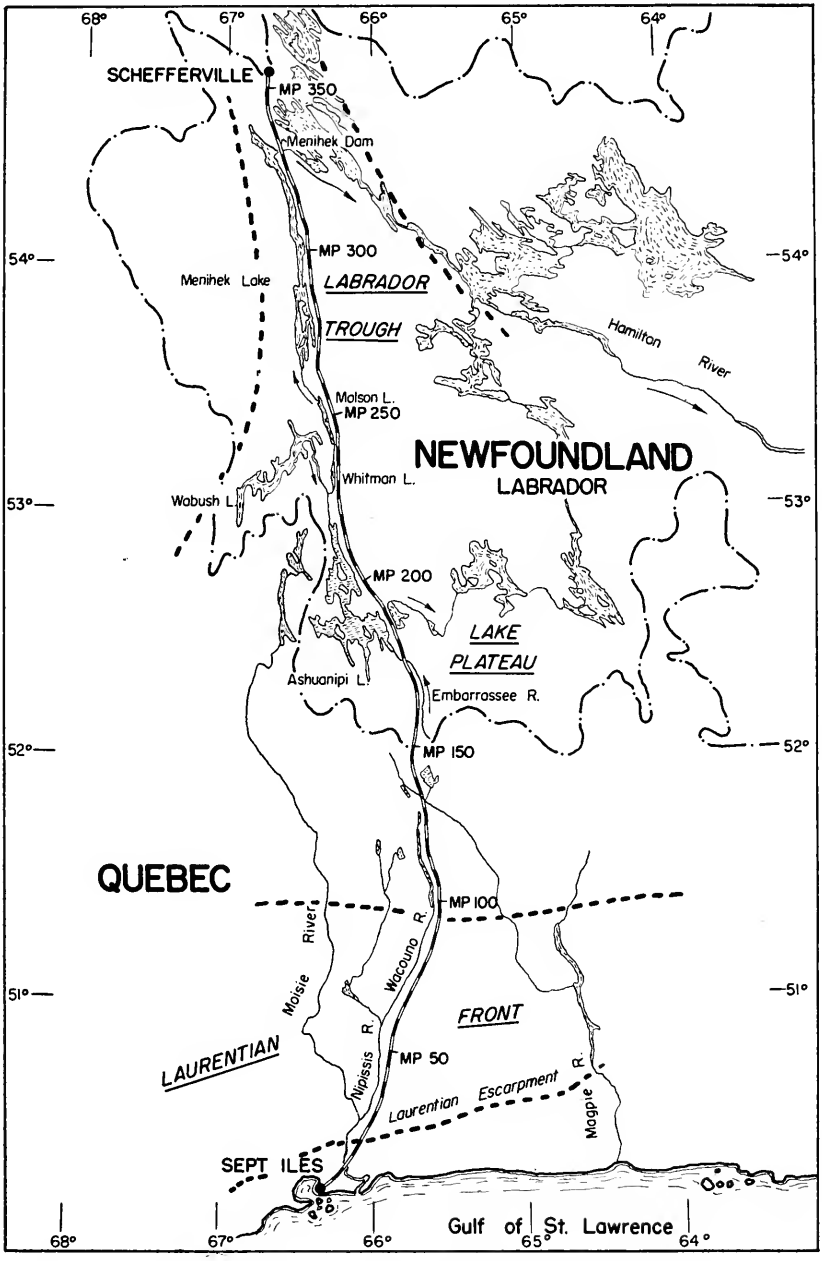
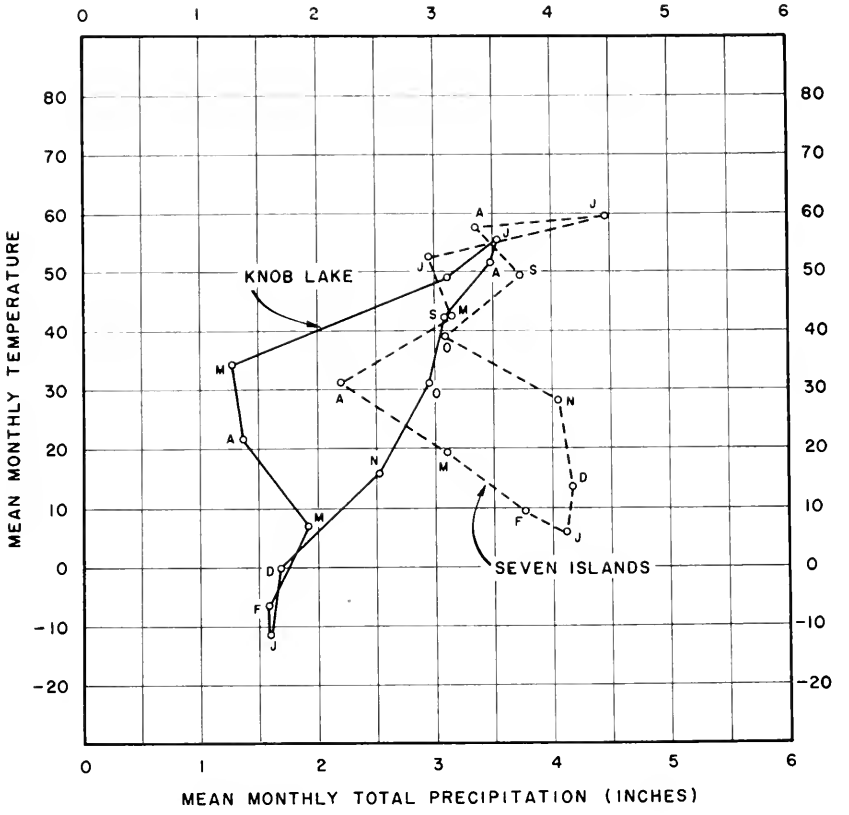


Fig. 1—Physiographic map of Labrador Peninsula showing location of railway *(adapted from* Canadian Geographer, No. 5, 1955, p. 9).



SEVEN ISLANDS LAT. 50° – 10 N LONG. 66° – 15 W (14 YEARS RECORDS)

KNOB LAKE LAT. 54° – 40 N LONG. 66° – 55 W (10 YEARS RECORDS)

Fig. 2—Composite hythergraph of Knob Lake and Seven Islands.

C. CLIMATE

The climate of the region varies from maritime at Sept Iles to sub-arctic at Schefferville (3). Fig. 2 shows hythergraphs for Schefferville and Sept Iles by which the climates may be compared in terms of mean monthly temperature and precipitation.

The coastal region is one of relatively high precipitation, the average annual precipitation at Sept Iles being 42 in. The heaviest monthly rainfall is close to 6 in and occurs generally in July. A second peak of precipitation occurs during the winter months when saturated air from the Gulf of St. Lawrence comes into contact with the steep slopes of the north shore. Annual snowfall is of the order of 170 in, while the heaviest monthly snowfall averages 50 in and occurs usually in January. On the Labrador Plateau (or in the region north of Mile Post 100) precipitation is more moderate. At Schefferville, the average annual precipitation is 28 in, of which rainfall

accounts for slightly more than one-half. The heaviest monthly rainfall amounts to 3.5 in and occurs in July and August, the only months during which snowfall is negligible. Annual snowfall is approximately 130 in. most of which is fairly evenly distributed over the months from October to April.

By way of further comparison, Sept Iles has temperature conditions comparable with Regina, Sask., and Schefferville with Dawson in the Yukon Territory. Both Sept Iles and Regina have mean average annual temperatures of 34 deg F, while the corresponding figure for Schefferville and Dawson is 23 deg F. The Quebec–Labrador area, however, does not experience the wide range from midwinter low to midsummer high temperatures common to both Regina and Dawson. The comparison cannot be extended to include precipitation; the annual precipitation at Sept Iles being almost three times that at Regina, and the annual precipitation at Schefferville more than twice that at Dawson.

D. VEGETATION

In the upland region south of M.P. 100, heavy precipitation, a cool climate and sandy soil have contributed to the development of a mixed coniferous and deciduous forest type of vegetation with spruce, balsam fir, and tamarack as the dominant species of tree. Birch is the principal hardwood. Poorly drained areas, lakeshores and the banks of streams support thickets of willow and alder. The forest floor is generally featured by a dense growth of ericaceous shrubs such as the Labrador Tea plant and blueberry which thrive upon the acid, humus soil. A ground cover of moss, lichens and fungi with some ferns and grasses has developed upon a relatively deep deposit of partially decomposed woody vegetable debris. The highly acid organic topsoil is rarely more than a few inches in depth and is usually underlain by an iron-oxide cemented stratum of glacial till from 1 to 2 ft thick. Forest cover becomes less dense on higher ground and rock is generally exposed on watersheds.

North of M.P. 100, the Labrador Plateau is characterized by open or timbered bogs with low shrubs, grasses and moss as the dominant type of vegetation. Tree cover becomes less pronounced to the north, and Schefferville is in a region of sparse tree cover.

In general, trees are not very large, and locating and procuring timber suitable for piling usually requires extensive aerial surveys and long access roads. Timber in the coastal area is of some commercial value for the production of pulpwood and lumber.

Throughout the region traversed by the railway, vegetation and climate contribute to the existence of an enormous insect population; timbered and waterlogged areas providing breeding grounds for blackflies and mosquitoes, respectively.

E. TERRAIN TRAVERSED BY RAILWAY

A sand plain of marine origin along the north shore of the Gulf of St. Lawrence is the first topographical feature crossed by the railway. The plain is relatively level with poorly drained areas covered by muskeg. At M.P. 10 the roadbed reaches several terraces of post-glacial marine clay and abruptly encounters the Laurentian Upland at M.P. 12. From M.P. 12 to M.P. 94 the roadbed follows deep valleys cut into precambrian granitic rocks by the Moisie, Nipissis, and Wacouno Rivers. South of M.P. 30 the Moisie and Nipissis rivers have eroded channels in the deep deposits of post-glacial silt and clay which comprise the valley fill. These fine-textured sediments

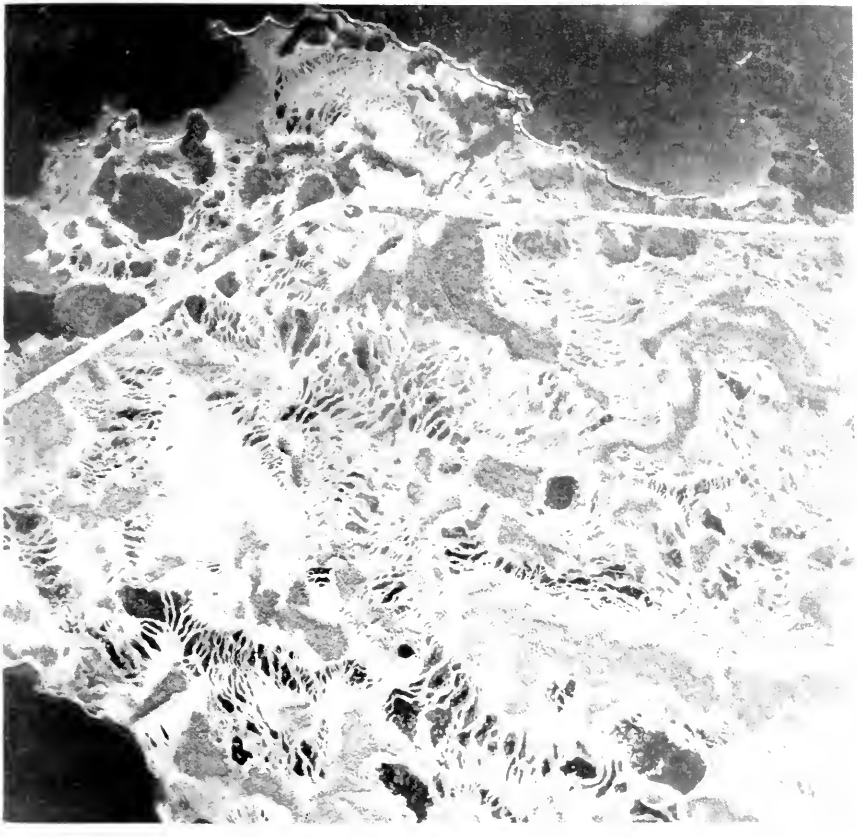


Fig. 3—Aerial view of terrain on Labrador Plateau (Photo: Royal Canadian Air Force).

are usually overlain by sands. Between M.P. 30 and M.P. 94 the soil mantle in the river valleys consists of sands and gravels.

From M.P. 94 to M.P. 260 the roadbed crosses the Labrador Plateau. The topography is featured by many lakes and by large tracts of poorly drained muskegs. Fig. 3 is an aerial photograph of the plateau from about M.P. 188. Under the organic cover the predominating soil formation is a sandy, glacial till. There are minor glacial deposits such as kames, eskers, and terraces and lacustrine deposits near the larger lakes.

From M.P. 260 to M.P. 360 the roadbed enters the great geological unit known as the Labrador Trough (4). Here, the soil formations resemble those of the plateau but are generally better drained. The Labrador Trough is featured by long, parallel ridges with their axes oriented in a north-northwest, south-southeast direction.

F. TYPES AND PROPERTIES OF SOIL FORMATIONS

Foundation and construction materials may be classified as: marine and fluviatile sands; banded clays; Laurentian Upland rock; stratified sands and gravels; sandy

glacial till; granular deposits from eskers and outwashes; lacustrine silts and sands; and muskeg or organic terrain.

1. Marine and Fluviatile Sands

The marine sands are beach deposits formed during the retreat of the Champlain sea at the close of the last period of glaciation (5). The sands are loose, uniform and stratified. Poorly drained muskeg sections on the coastal sand plain presented minor drainage problems, but generally the sand was easily handled by construction equipment, and its use in the roadbed has caused no difficulties.

2. Banded Clays

In the drowned section of the Moisie valley between M.P. 16 and M.P. 28, massive deposits of banded clays are overlain by varying depths of sand and gravel. The clays form part of the Champlain Sea deposits known as "Leda" clay (5), a particularly troublesome soil from the slope stability aspects and notorious for the occurrence of large-scale landslides and earth flows. Occasionally, the clays are underlain by, or interbedded with, relatively deep deposits of uniform sand. The Moisie River, in eroding its present channel, has removed much of this valley fill, leaving many terrace remnants—some with heights in excess of 130 ft. Several miles of railroad subgrade are located in these terrace materials in cut and fill sections. Several slides have occurred to date and the probable occurrence, within the past century, of several additional massive earth movements is indicated by the study of aerial photographs and on-foot studies.

The banded nature of the marine "clays" encountered in the Moisie Valley causes the results of physical tests to vary widely (6). Generally, however, the sediments may be described as silty clays and silty fine sands. Typical grain-size analyses indicate about 15 percent sand-size, 50 percent silt-size and 35 percent clay-size particles. Bedding planes are rarely horizontal and in many instances slope towards the river, sometimes very severely. Test data obtained from samples taken between M.P. 11 and M.P. 24 and at depths extending to 160 ft show the most troublesome soils to have natural water contents in excess of the liquid limit. The following average values are based upon tests on more than 700 composite samples:

Natural water content	38 percent
Liquid limit	34 percent
Plasticity index	15 percent

The liquidity index (the ratio of the natural water content minus the plastic limit to the plasticity index) ranges from about 0.4 to 2.7, with an average value of 1.3. Values in excess of unity indicate soils which are sufficiently sensitive to remolding that vibration or other disturbance may result in liquefaction.

Unconfined compression tests and vane shear tests indicate an average shear strength of approximately 2000 lb per sq ft,—a value which should be adequate to ensure the stability of all natural and cut slopes encountered in the Moisie Valley. Stability analyses are complicated, however, by the presence of permeable strata and unusual groundwater conditions, the inclination of bedding planes and by the fissured character of the sediments.

3. Laurentian Upland Rock

As a result of preglacial uplift and greatly modified glacial and post-glacial drainage, the Moisie River has eroded a deep trench in the hard rocks between M.P. 16

and M.P. 12, having abandoned an older and much deeper channel to the west. The railway follows the Moisie River through this rock area. Between M.P. 59 and M.P. 73, it was necessary to locate the railway well above the level of the Wacouno River in order to negotiate the numerous falls and rapids. In both of these areas the roadbed is founded either on benches cut into the valley wall or on high rock fills. A 2200-ft tunnel was required at the approach to the Moisie River crossing at M.P. 12, and a second tunnel, 800 ft long, was necessary at M.P. 65 in a steep-sided section of the Wacouno valley.

The valley of the Moisie between M.P. 12 and M.P. 16 contains no unconsolidated material of importance, while between M.P. 59 and M.P. 73 such deposits as do exist are close to the narrow floor of the Wacouno River valley. Maintenance problems in these locations (other than those normally associated with heavy grades and tortuous alinement) are confined to icing difficulties. The rock is generally jointed and fissured, and water seeping towards the roadbed during the winter months may cause ice to accumulate in side ditches and eventually to over-run the track. Severe conditions occur in the vicinity of the tunnels at M.P. 12 and M.P. 65 where heating cables are necessary in order to keep the side ditches open.

Construction in these rock areas presented few direct problems, but the time-consuming operation of heavy rock excavation (1 million cu yd between M.P. 12 and M.P. 16) was a serious handicap to road communications. In order not to delay the movement of equipment and supplies to more northerly working points, it was necessary to construct and maintain approximately 25 miles of haulage road bypassing each of the two heaviest rock cut sections. In the Moisie River section, the road was located, for the most part, in banded clays on the west side of the river. A wooden pile trestle carried this road across the Moisie River at M.P. 17. Demolition of the trestle by ice during the spring, and the difficulty of maintaining the road, restricted this expedient to the winter months of two successive years. Fortunately, the sand and gravel cover overlying the banded clays in the vicinity of M.P. 22 was of sufficient vertical and areal extent to permit the construction of an airstrip, which helped to overcome the difficulty.

The road which bypassed the Wacouno valley rock cuts was located partly through the coarse gravel and boulders of the valley floor and partly on higher ground. Prefabricated (steel) bridges were used to carry this road across the Wacouno River in two locations. In this area too, it was possible to relieve a difficult situation by the provision of airstrips, since suitable coarse-textured soils were available in adjacent wider sections of the valley at M.P. 54 and M.P. 84.

A rock quarry at M.P. 16 is the source of rip-rap stone used for the protection of embankment slopes in the river valley sections of the railway.

4. Stratified Sands and Gravels

These materials are of glacio-fluvial origin and are plentiful in the valley of the Nipissis River. South of M.P. 28, in the Moisie valley, sands with some gravel overlie the banded clays and fill depressions and former erosion channels. In the valley of the Wacouno River, north of the falls at M.P. 73, extensive deposits of outwash material are the source of much prepared gravel ballast. Other ballast pits at M.P. 22 and M.P. 48 provided gravel suitable for sub-ballast and bank-widening during the final stages of construction.

The volume of earth work involved in the construction of the roadbed through these stratified soils was of the order of 4 million cu yd, but their coarse textured

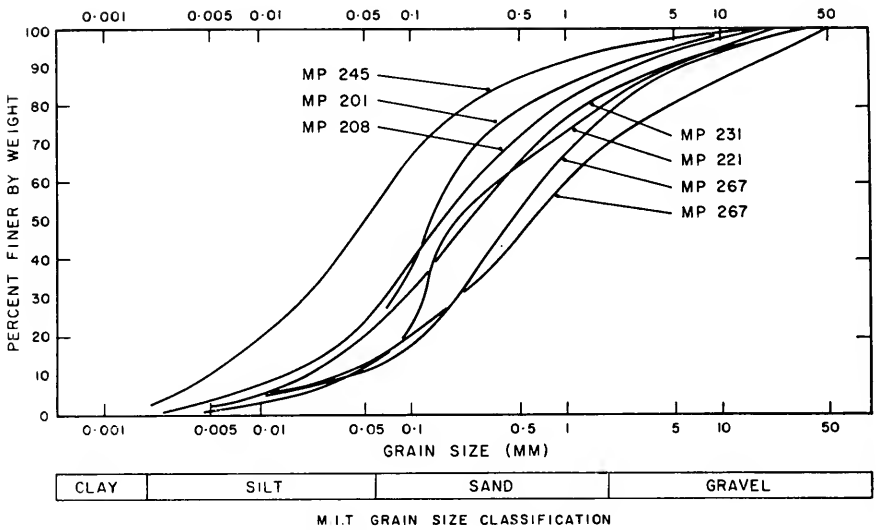


Fig. 4—Grain-size curves for sandy till.

nature caused little difficulty. A few cuts located in the wider sections of the Nipissis valley (M.P. 36 and M.P. 51) encountered very silty soils which were wasted.

In the two narrower sections of the Nipissis Valley, between M.P. 30 and 34 and M.P. 40 and 49, buried rock terraces occur, and sloping bedrock surfaces may underlie high side-hill cut slopes in sand and gravel. Here, seepage has resulted in troublesome conditions which are discussed later in the paper.

5. Sandy Glacial Till

As the alinement passes beyond the influence of the river valleys, the predominant soil formation becomes a sandy glacial till. Grain-size distribution curves for samples of this material from the Ashuanipi Lake area (M.P. 201 and M.P. 221) are shown in Fig. 4. A well-graded sandy soil, the till has proved to be a good embankment material. Because of the low in-place density and high moisture content, however, these soils were often difficult to place during grading operations. Fig. 5 shows a cut section at M.P. 201 and illustrates the type of problem encountered. North of M.P. 270, soils were generally better drained and caused little difficulty.

In the vicinity of Menihek Dam at M.P. 330, the coarse-textured and generally well-graded glacial till provided the 650,000 cu yd of material required for the rolled, homogeneous earth-fill sections of the dam (7). The fill was placed in 6- to 8-in lifts, using both trucks and rubber-tired tractor-scrapers and compacted by tractor-drawn sheepsfoot rollers. A sand and gravel underfilter beneath the downstream slope was incorporated in the fill by excavating and backfilling. Upstream sides were constructed with submerged slopes of 3:1 and upper slopes of 2:1. These slopes were provided with a coarse gravel blanket and toe, and the upper sections protected by rip-rap stone quarried locally. Downstream slopes of 2.5:1 were provided with a toe of riverbed boulders or coarse gravel and protected by a gravel facing. Suitable gravel for this

Fig. 5—Construction difficulties caused by liquefaction of till resulting from action of construction machinery, Mile 201 (Photo: G. D. Creelman).

purpose was not readily obtained in the Menihek area and was hauled from the ballast pit at M.P. 290 after construction.

Construction of the rolled fill sections of the dam was begun in May and completed in October 1953, a summer of unusually light precipitation, and was not seriously affected by adverse moisture conditions.

In the Labrador Trough region, gravelly soils with a high percentage of clay-size particles have proved to be susceptible to frost, and in a few locations heavy differential heaving in the winter months has been followed by the appearance of mud boils as late as July. As the grain-size distribution curves show, some of the till of the Ashuanipi Lake area is a borderline soil using Beskow's criterion for frost-susceptible morainic soils (8). Some frost heaving has occurred in this material.

6. Granular Deposits From Eskers and Outwashes

A fortunate circumstance from an engineering aspect is the existence on the Labrador Plateau of extensive deposits of coarse-textured granular material in the form of eskers and other granular landforms. Several large borrow pits were established at the close of the track laying phase to provide the fill with which embankments were widened and brought to grade, using train-haul methods. Suitable deposits in the form of eskers were located for this purpose at M.P. 134, M.P. 223 and M.P. 290. At M.P. 84, near the head of the Wacouno River valley, a well-graded outwash formation provided another source of excellent material. The better and more favorably located of these pits (M.P. 84 and M.P. 290) continue to supply crushed and screened railway ballast and coarse aggregate for concrete.

Transportation requirements during the construction period made the location of

airstrips, suitable for use in all seasons, an important consideration. The 5000-ft runways constructed at M.P. 134, M.P. 224 and M.P. 290 are examples of the excellent use which may be made of glacial deposits from eskers. In connection with the construction of airstrips, it is fortunate that the north-south trend of most granular landforms coincides with the direction of the prevailing northwest winds.

7. Lacustrine Silts and Sands

Between M.P. 180 and M.P. 280, the alinement follows closely the shorelines of Ashuanipi, Whitman, Molson, and Menihek Lakes and passes through many areas with poor internal and surface drainage. Here the soil profile frequently shows that deposits of lacustrine silts and sands overlie the till with a surficial cover of muskeg. As a result of the high water table, cuts in this material invariably produced "near-quick" conditions. The silts were generally excluded from the roadbed and have proved to be troublesome in the more or less local situations where they were placed in fills. During the construction period, every effort was made to use completed or partially completed sections of the railway subgrade as a haulage road, and encounters with these fine-textured materials were the cause of much distress.

Between M.P. 95 and M.P. 120, in the wide basin now occupied by the relatively narrow Wacouno Lake, many shallow cuts were necessary in silty fine sand and also in much coarser but poorly graded soils with a large proportion of fines. These soils were fairly well drained and presented little difficulty during construction, but are highly susceptible to frost and have performed badly in this repect.

8. Muskeg

The combination of imperfect drainage, high precipitation, and a cold climate has resulted in the development, on the Labrador Plateau, of an almost continuous cover of shallow muskeg or partially decayed fibrous organic matter. Along the route of the railway, the most extensive areas of muskeg are located in the drainage basins of the larger lakes and at the headwaters of such streams as the Wacouno and Embarrassée Rivers. The depth of this organic cover seldom exceeds 3 or 4 ft and although deeper deposits do exist, they were avoided whenever possible. The material consolidated rapidly after the placing of fills and differential settlement has been unimportant. The most serious difficulties occurred during construction when wide detours were often necessary in order to carry the all-important haulage road past incomplete sections of the railway subgrade.

G. CONSTRUCTION AND MAINTENANCE PROBLEMS

1. Slides in Banded Clays

Slope stability in sections of the stratified silts and clays is being studied extensively. The landslide problem became apparent in the spring of 1951 when, during construction of the tunnel at M.P. 12, the rock roof collapsed about 200 ft from the south portal allowing the overlying silty clay to cave in. The resulting disturbance caused the material to liquefy (the liquidity index of the clay in this locality has been found to be close to 2) and some 60,000 cu yd of clay poured through the tunnel roof and flowed through the south portal before equilibrium was restored. To prevent the occurrence of further mud flows during reconstruction of the tunnel roof and to facilitate this operation, an additional 40,000 cu yd was excavated hydraulically.

Fig. 6—Slide in the silty clay bank at Mile 12 (Photo: G. D. Creelman).

A second earth movement involving 3000 cy yd of silty clay took place at the same tunnel in September 1953. On this occasion, the failure took the form of a circular slip in the cut slope at the approach to the south portal. The original slope had a vertical height of 70 ft and was excavated at 1.5:1. Fig. 6 shows the failure shortly after the right-of-way had been cleared.

As a remedial measure, about 7000 cu yd of soil were excavated from the shoulder of the slope to form a bench 30 ft in width and 50 ft above the shoulder. Despite the resulting reduction in driving moment, a further failure involving the material below the bench occurred in the spring of 1954.

Using the actual slip circles and shear strength values derived from unconfined compression and vane tests, $\phi = 0$ stability analyses indicated theoretical factors of safety of about 2.0 in the case of both slope failures. Borings undertaken in 1956 disclosed the presence of a continuous sand stratum between the banded sediments and the underlying bedrock surface which outcrops a few hundred feet from the shoulder of the cut slope. Three days prior to the first slide, 3.79 in of rain were recorded during a 24-hr period, while the second slide occurred at a time when melting snow caused the groundwater table to be at its highest. It seems probable, therefore, that the development of high hydrostatic pressures within the confined sand stratum may have contributed to the failures.

During the spring of 1955, a third failure was anticipated, and an unstable section of the slope was induced to fail by blasting. Removal of the debris and excavation of a drainage ditch at the toe of the slope exposed the buried sand stratum, and no additional failures have occurred to date.

Construction of the roadbed through the banded clay soils of the Moisie valley frequently required the excavation of benches in the natural riverbank slopes. In these sections, failures may involve an entire slope or may be confined either to the cut slope above track level or to the embankment slope beneath the roadbed. To date, no failure has involved an entire slope of this type, but there have been some slides in both cut and embankment sections. On April 25, 1955, a failure of the latter type occurred at M.P. 19.5. The track structure at this location was supported by a granular fill founded largely on the riverbank slope and deriving little support from a narrow bench cut into the side of the original slope, just below track elevation. Failure of the clay slope below the bench caused 15,000 cu yd of fill to slide into the Moisie River on a 150-ft front, leaving the track suspended.

It has been mentioned previously that stratified sands and gravels overlie the banded clays and occupy local depressions in the surface of these deposits. An example of the latter condition exists at M.P. 18.6 where a 60-ft side hill cut was made in an apparently extensive deposit of banded silty clay, overlain by a shallow cover of gravel and sand. Four years after completion of the cut, borings disclosed that at one point the granular cover close to the shoulder was actually 90 ft in depth, with the groundwater table close to the surface. Extensive drainage measures were required to lower the water table in this pocket of saturated sand.

A number of factors may thus be said to contribute to the landslide problem and make theoretical stability analyses extremely difficult to apply to design. Such factors include the following:

a. The banded silty clays have high liquidity indices and become unstable with vibration or other disturbance. There is always a danger that a minor slope failure may develop retrogressively into a "mud flow" of some proportions.

b. Non-uniformity of the formations, variations in thickness and character of the bands, the presence of sandy strata and the inclination of bedding planes.

c. Because of high relief of the valley walls in the locations where these materials occur, there are many sections where high hydrostatic pressures can develop. With a high water table in the granular overburden, heavy summer rainfall (the month of July averages 4.5 in) and a rapid run-off, drainage at the shoulders of the slopes is critical in order to prevent erosion and the development of seepage pressures.

2. Sloughing of Slopes

This problem is the most serious manifestation of the effect of frost in the section south of M.P. 28. As indicated by Fig. 7, the silty clay is particularly troublesome in this respect. Despite the fact that wind tends to prevent the accumulation of snow on cut slopes, frost penetration is restricted to 18 or 24 in by the high moisture content of the clay. Conditions are conducive, however, to the formation of ice lenses. These form ideal sliding surfaces for the overlying material which begins to slough into side ditches with the first periods of warm sunshine in the spring. Ditches are thus frequently obstructed even before the snow has begun to melt, and the problem usually persists until June, requiring a considerable amount of maintenance.

Cut slopes exposed to several winters tend to become more stable from the standpoint of sloughing as a weathered surface layer some 2 ft thick develops. This weathered crust does not support the growth of ice lenses to the same extent as the parent material and is more tolerant of vegetation. Efforts are therefore being made

Fig. 7—Sloughing of slopes in banded silts (Photo: J. A. Rodriguez).

to establish deep-rooted vegetative cover on slopes which are considered to be stable apart from a tendency to slough. The use of a blanket of granular material on cut slopes in clay has been found to be beneficial in certain circumstances. An important prerequisite in such cases is the absence of seepage along the sand-clay interface.

3. Deep Cuts in Gravels

Seepage and heavy precipitation have been responsible for several examples of sloughing in sands and gravels. At M.P. 32.8 in June 1955, a movement which approached the proportions of a slide occurred in sand overlying a steep buried rock slope and was apparently triggered by the passage of an ore train. The vertical height of the slope was 220 ft, with the crest of the buried rock slope some 40 ft below the shoulder. Seepage from a small pond located about 800 ft from the shoulder of the slope is believed to have contributed to the slide in which 2000 cu yd of waterlogged sand sloughed from the upper part of the slope, derailed a train, and buried the track to a depth of 15 ft. A rainstorm (0.26 in) 11 days prior to the slide resulted in several minor slides in the lower part of the slope, a factor which may have affected the over-all stability of the slope.

Fig. 8 is drawn from an aerial photograph of the location and illustrates the position of the pond with respect to the failure of the slope. Through the use of airphotos and ground surveys, all potentially dangerous slopes are being investigated and, where necessary, measures are being taken to drain perched lakes.

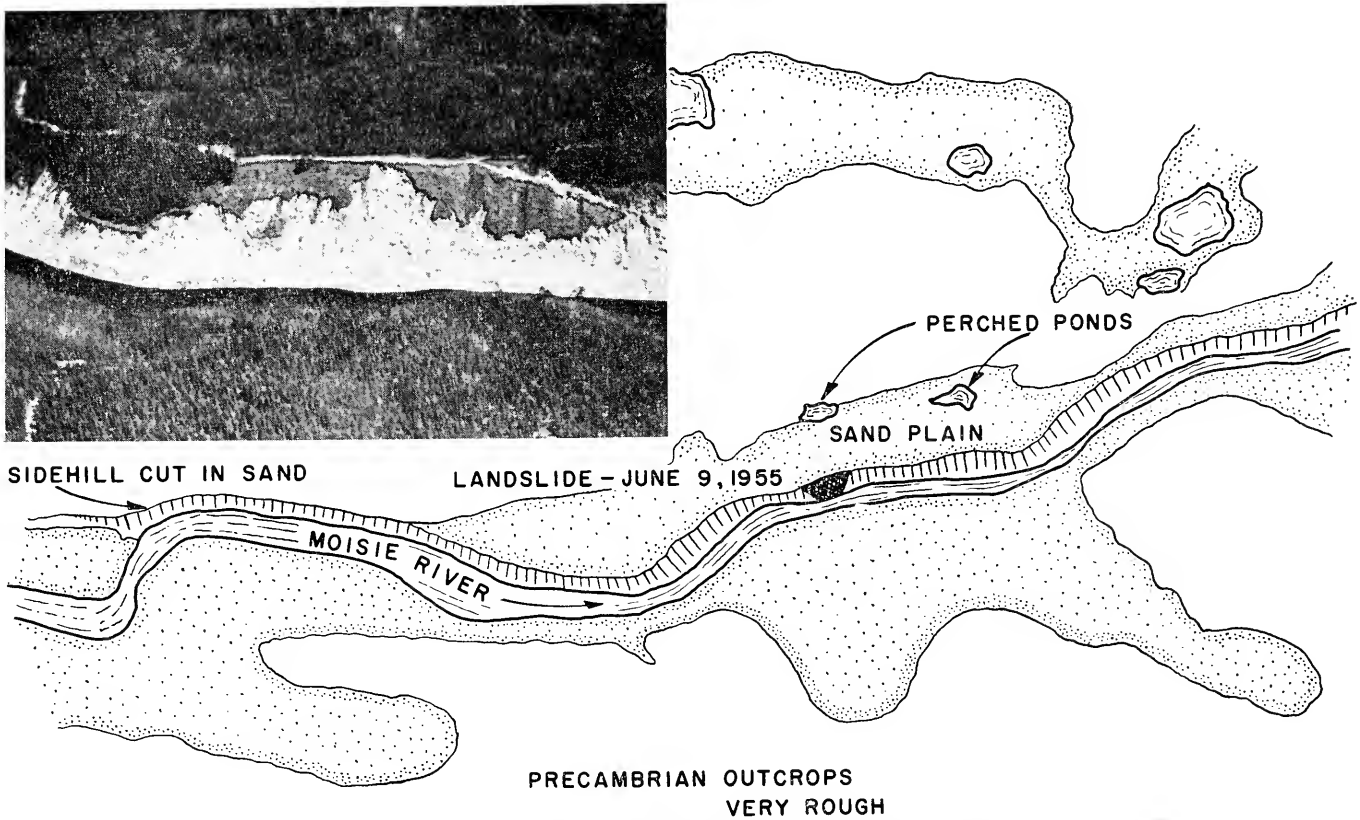


Fig. 8—Location of landslide at Mile 32.5 (traced from RCAF airphoto No. A14460-19). Inset: aerial view of cut at Mile 32.5 (Photo: B. M. Monaghan and J. A. Rodriguez).

Fig. 9—Condition of grade during construction in silty area (Photo: G. D. Creelman).

4. Muskeg

The initial procedure followed in construction through muskeg sections called for the use of light draglines supported on timber rafts or mats, and was facilitated by the generally shallow depth of the organic cover. These machines, working in pairs one on each side of the proposed roadbed, excavated side ditches by wasting the organic material and silt, and casting enough of the underlying till onto centerline to form a trafficable road. The subgrade was later completed using carry-alls or trucks hauling from available borrow pits. Since much of the granular glacial till was of a silty character, this procedure made it inevitable that in some instances silty material was incorporated in the roadbed in a wet, loose condition. Because of the low relief, ditches were not always effective in removing water and, under these circumstances, equipment was frequently mired in the grade. Fig. 9 indicates the unstable conditions which developed on occasion, especially during wet weather.

Shallow cuts encountered in the muskeg area often proved troublesome; even glacial till having a tendency to liquefy when exposed to traffic, as Fig. 5 illustrates. The results of Proctor density tests conducted on samples taken from stable and unstable sections of the same fill at M.P. 267 are shown in Fig. 10. Since the grading of the samples was substantially the same (Fig. 4), the cause of the instability was clearly lack of adequate compaction and excess moisture content. In very wet locations, relief from the effect of the high watertable was obtained by using dynamite to blast offtake ditches before construction began.

Since haulage roads between construction camps necessarily made wide detours around muskeg sections, access to working points was a major difficulty. Advantage

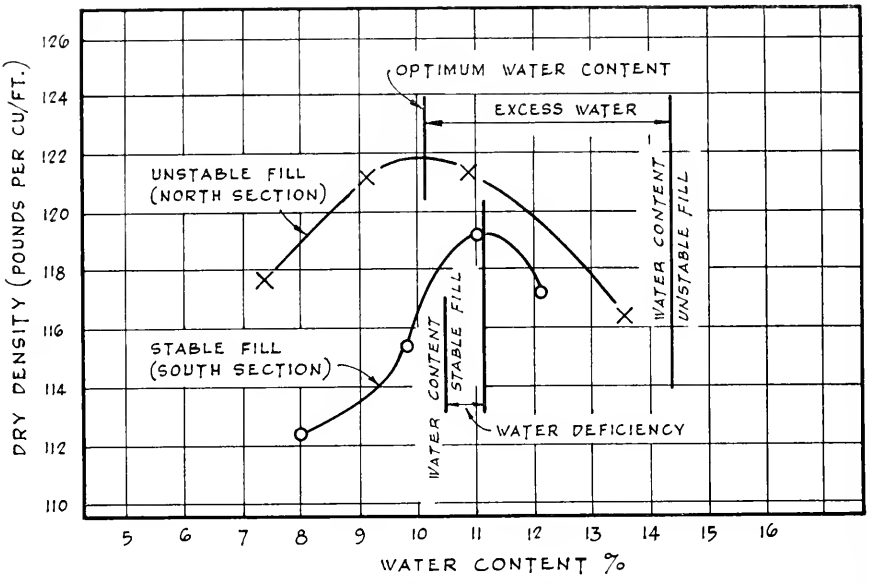


Fig. 10—Curves showing the relationship between dry density and water content as found by the Standard Proctor Compaction Test.

was taken of frozen ground at the end of the winter season to locate machines strategically in readiness for the spring. In the case of the more isolated locations, it was necessary to use canoes and boats in order to service machines and transport personnel.

5. Concrete Aggregates and Ballast Materials

The organic contamination of sands and gravels is general throughout the region. In the case of minor concrete structures, it was usually possible to locate acceptable gravel deposits for concrete aggregate within a reasonable distance of construction sites, but long hauls were occasionally required.

Pit-run material from the stratified sands and gravels of the lower Moisie and Nipissis valleys provided suitable graded aggregates for the construction of bridges at M.P. 30 and M.P. 40. The same deposits also supplied much of the aggregate required for construction in the terminal area of Sept Iles, although a quantity of good quality aggregate was imported by boat. For major structures, such as the Ste. Marguerite Dam, 20 miles west of Sept Iles, and the Moisie River bridge at M.P. 12, local gravel deposits supplied the fine aggregate, while coarse aggregate was prepared by crushing and screening rock quarried locally.

The gravels associated with the glaciated river valleys and the granular landforms of the Labrador Plateau are derived from many types of rock. In general, the presence of granite gneiss characterizes the gravels of the Upper Wacouno River valley, while metamorphic schists with quartzite as the predominant material are characteristic of the Labrador Plateau. When crushed and screened, the gravel from these sources is suitable for both railway ballast and concrete aggregate.

The rocks of the Labrador Trough area are usually dense, fine-grained and have a

tendency to break into harsh angular fragments with flat elongated shapes. The crushed product has a high abrasion resistance and despite its highly fissile nature is acceptable as railway ballast. Owing to the presence of such undesirable constituents as chert, phyllite and iron pyrites, however, the rocks are generally unsuitable for use as concrete aggregate. This situation, and the absence of clean gravels, necessitated the use of a highly contaminated deposit of stony glacial drift as the source of concrete aggregate for the Menihek Dam at M.P. 330 (7). This deposit comprised stones derived from the local bedrock, together with quartzitic cobbles and boulders. Washing and screening removed most of the organic contamination along with the fines. Subsequent crushing and sand-roll operations reduced the large quartzitic cobbles to a maximum size of 2 in and improved the grading by restoring the proportion of sand-size particles.

H. FROST ACTION AND ROADBED MAINTENANCE

1. Ground Temperatures

The region traversed by the railway is noted for heavy precipitation and severe winters; the effect of frost action on the performance of the roadbed is thus a major consideration. At the outset, the problem was confounded by a lack of information on the depth of seasonal frost penetration and meager data on air temperatures. To surmount this difficulty, a program of ground temperature measurements was started to study the thermal regime in typical soils under various conditions of exposure and surface cover. Three field installations were made—at Schefferville, at M.P. 266, and at Sept Iles (9).

The study of frost penetration along the railway route is being coordinated with the broader study of climatic data and soil temperatures which is being conducted by the Division of Building Research of the National Research Council (10).

2. Maintenance

Problems attributable to frost action include the following: (a) differential heaving of track and softening of the roadbed on thawing, (b) sloughing of cut and embankment slopes, (c) icing of track and culverts due to side-hill seepage.

a. Frost Heaving of Track

Improved drainage and the use of admixtures such as sodium chloride, calcium chloride and calcium lignosulphonate are two of the measures adopted to surmount the problem. All three admixtures have been effective in reducing the amount of heave, but their relative value is difficult to assess since track-raising and drainage improvements have also contributed. Complete excavation of frost-susceptible soils and replacement with granular materials has been undertaken in some locations.

b. Sloughing of Slopes

This aspect of frost damage has been discussed in connection with the banded clays of the Moisie valley where the problem is particularly severe. In the muskeg sections of the Labrador Plateau some sloughing of low embankment slopes into side ditches occurs during the spring run-off period as the frost leaves the ground. This condition has been relieved by widening embankments with coarse granular material.

c. Icing

The icing problem has been mentioned in connection with rock cut sections of the railway, but it also occurs in sidehill cuts elsewhere. The difficulties caused by this

condition have been eased by the diversion of surface water and measures designed to prevent culverts from becoming obstructed.

3. Permafrost

During construction operations in 1953, two locations where frozen soil was encountered in September suggested that permafrost was a definite possibility in Labrador. At M.P. 245, a shallow cut revealed frozen ground with ice lenses 3 in thick extending to a depth of 6½ ft. It was very unlikely that this frost would leave the ground before the onset of the next freezing season. At this location, a winter haul road crossed the grade line and might have fostered a deeper than normal seasonal frost penetration. At M.P. 253 frozen soil was again encountered, in this case at a location where there was no haul road. These occurrences of frozen soil strongly suggest that scattered islands of permafrost do occur. Further, if the frozen ground at M.P. 245 did result from the winter haul road, then the possibility exists that grading operations may cause permafrost to develop under certain conditions.

4. Ballasting

One beneficial effect of extreme low temperatures may be cited in connection with the distribution of ballast. Completion of the track laying program in February 1954 made it necessary to stabilize the skeleton track by the distribution of coarse gravel ballast during the winter months. It was found that relatively dry gravel could be hauled any required distance and dumped, if it was allowed to freeze before loading and if the air temperature did not rise above approximately 15 deg F. At higher temperatures the material ceased to be free-running and tended to agglomerate in the cars.

I. CONCLUSIONS

Although long recognized as being potentially of great economic importance, the Labrador Peninsula remained a relatively inaccessible region until comparatively recent years. The airplane (and more particularly the floatplane) has done much to alter this situation, and aerial photography has provided an excellent engineering tool to aid in the development of the region.

Photogrammetry has facilitated mapping while the use of aerial photographs in connection with route surveys, drainage schemes, and site location will continue to play an important role in the planning and execution of engineering projects. Apart from the value of aerial photographs in simplifying location and survey work, airphoto interpretation can provide much information on unconsolidated deposits and soil conditions. This is information that can be procured only with difficulty using conventional methods.

Most of the difficulties encountered during and subsequent to construction of the Quebec North Shore & Labrador Railway have been of a regional nature, and similar problems, with local variations, are likely to occur throughout a large section of the Labrador Peninsula. Because of the close relationship between topography and the character of glacial deposits, one of the most satisfactory ways to approach these problems is through an appreciation of the glacial and post-glacial history of the region.

In general, the most serious construction problems are related to the excavation and placing of wet soils. The loose, wet condition in which many soil deposits occur accounts for the difficulty experienced even with granular till—normally considered to give satisfactory performance.

Maintenance problems arise from two principal causes: the effects of frost action and the instability of slopes. In a climate with high precipitation and very low winter temperatures, the effects of frost action become a major design consideration and one which should be recognized in the early stages of planning. Much can be done with respect to identification and mapping of frost-susceptible soils before a final location is established. At a later stage, the proper design of earthworks can do much to minimize effects of frost action such as heaving, icing and the sloughing of slopes. In the central section of the Labrador Peninsula, the effect of permafrost becomes an equally important consideration.

The stability of slopes in banded clays is a persistent problem in the southern section of the region. Since the slopes or river banks and terraces tend to be unstable in their natural state, every effort should be made to avoid construction in these locations. When relocation is impracticable, construction operations should be so directed that nothing is done to decrease the stability of natural slopes. Maintenance practices in these unstable sections should be preventive as well as remedial, and should be based upon the regular inspection of slopes and drainage facilities. Accumulation of records of the physical properties of clay soils and detailed investigation of failures are of inestimable value in planning a rational approach to the problem of maintenance.

J. ACKNOWLEDGMENTS

This paper is a joint contribution from the School of Civil Engineering, Purdue University, the Quebec North Shore & Labrador Railway Company, and the Division of Building Research, National Research Council, Canada. In preparing the paper, the authors received encouragement and advice from their colleagues in each organization. Particular acknowledgment is due to B. M. Monaghan, chief engineer, Quebec North Shore & Labrador Railway, with whose permission this paper is published, and to R. F. Legget, Division of Building Research, National Research Council, who approved of the contribution from the Division.

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Report on Assignment 8

Fences

L. J. Deno (chairman, subcommittee), F. N. Beighley, J. G. Gilley, L. V. Johnson, G. F. Nigh, J. A. Noble, W. O. Trieschman.

After making a canvass of roads represented by committee members as to their present standards for right-of-way fences, your committee came to the conclusion that some changes are necessary in our present specifications. In general, it was decided to include illustrations of the four classes of recommended right-of-way fences; to change the recommended span length from 20 ft to 16 ft 6 in; and to revise the section on materials to include all the types of fence posts for which there are specifications in the Manual.

The specific recommendations of your committee are as follows:

Pages 1–6–10 to 1–6–14, incl.

SPECIFICATIONS FOR RIGHT-OF-WAY FENCES

Reapprove with the following revisions:

Page 1–6–10: Change present Arts. 2. Class A Fence; 3. Class B Fence; 4. Class C Fence; and 5. Class D Fence to read "2. Class A Fence (See Fig. 1); 3. Class B Fence (See Fig. 2); 4. Class C Fence (See Fig. 3); and 5. Class D Fence (See Fig. 4)", respectively.

Insert the illustrations designated as Figs. 1, 2, 3, and 4 (presented herewith) immediately following page 1–6–10.

Page 1–6–11: Delete Arts. 1, 2 and 3 and substitute the following:

1. Intermediate or Line Posts

See Specifications for Wood, Concrete or Metal Fence Posts in this Chapter.

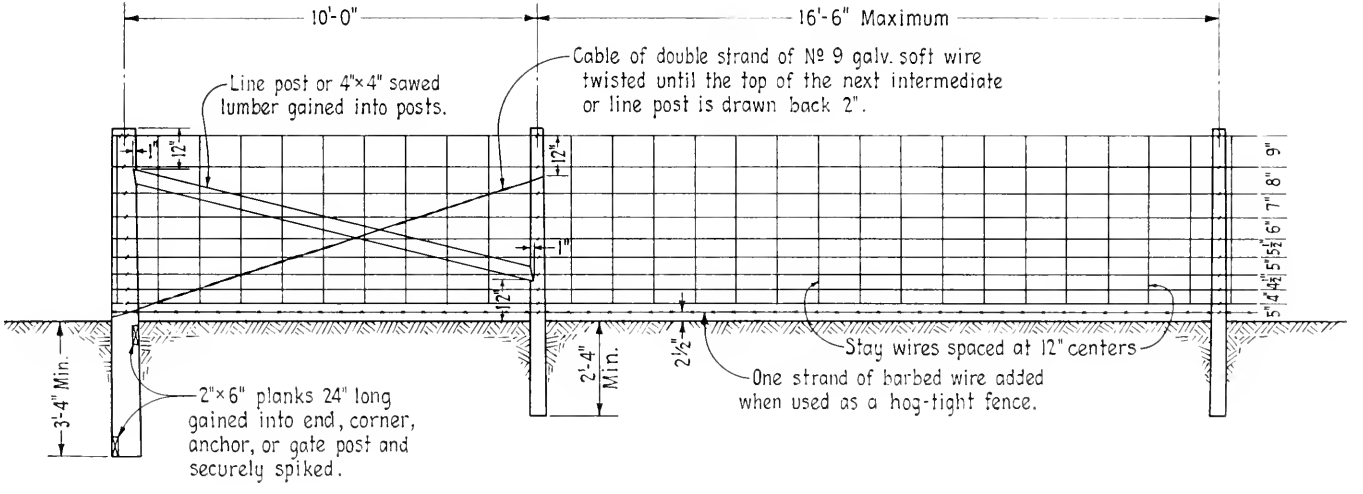
2. End, Corner, Anchor and Gate Posts

See Specifications for Wood, Concrete or Metal Fence Posts in this Chapter.

Redesignate Arts. 4 to 8, incl., as Arts. 3 to 7, incl.

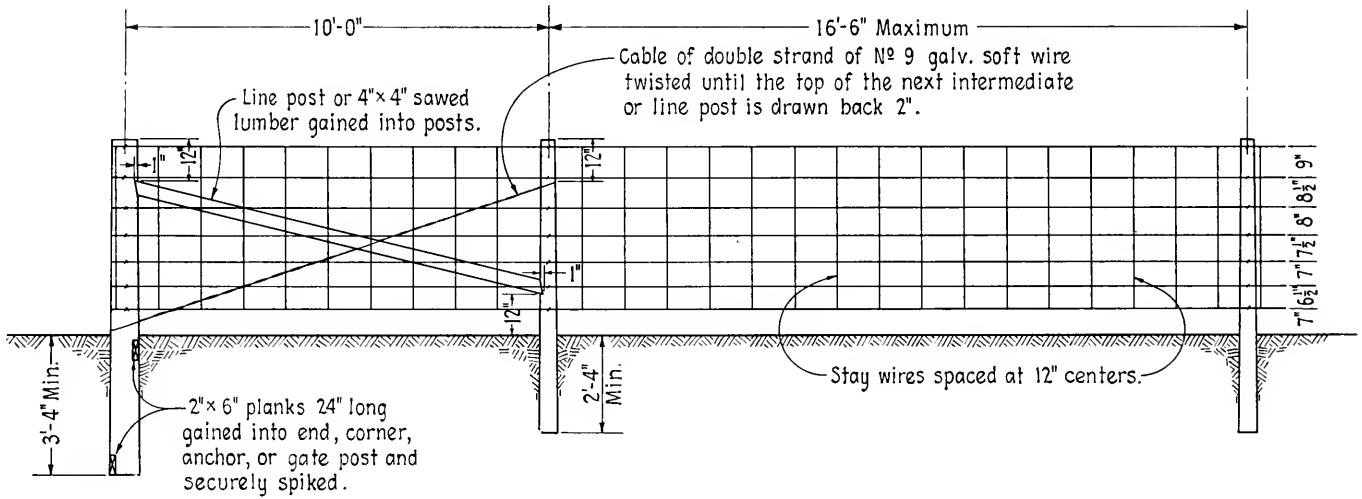
Page 1–6–12: Redesignate Art. 9 as Art. 8.

In the second line of Art. 2, Sec. C, Change "20 ft" to read "16 ft 6 in."



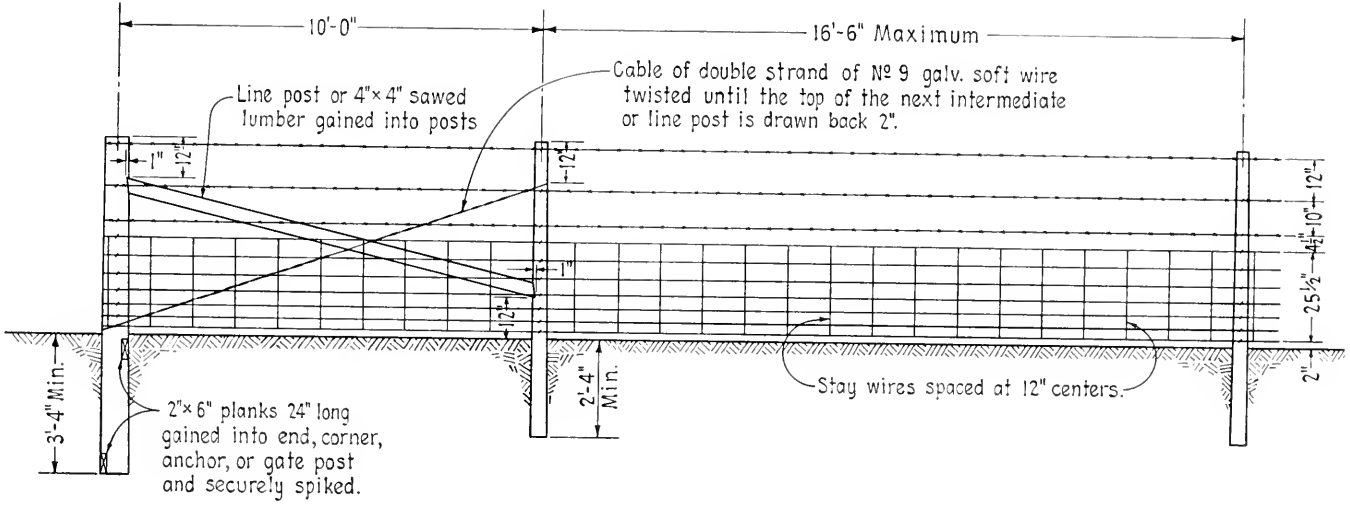
Class "A" fence shall consist of 9 longitudinal smooth galvanized steel wires.
Longitudinal and stay wires shall be № 9 gage.
Fence posts may be wood, concrete or metal as specified in this Chapter.

Fig. 1.



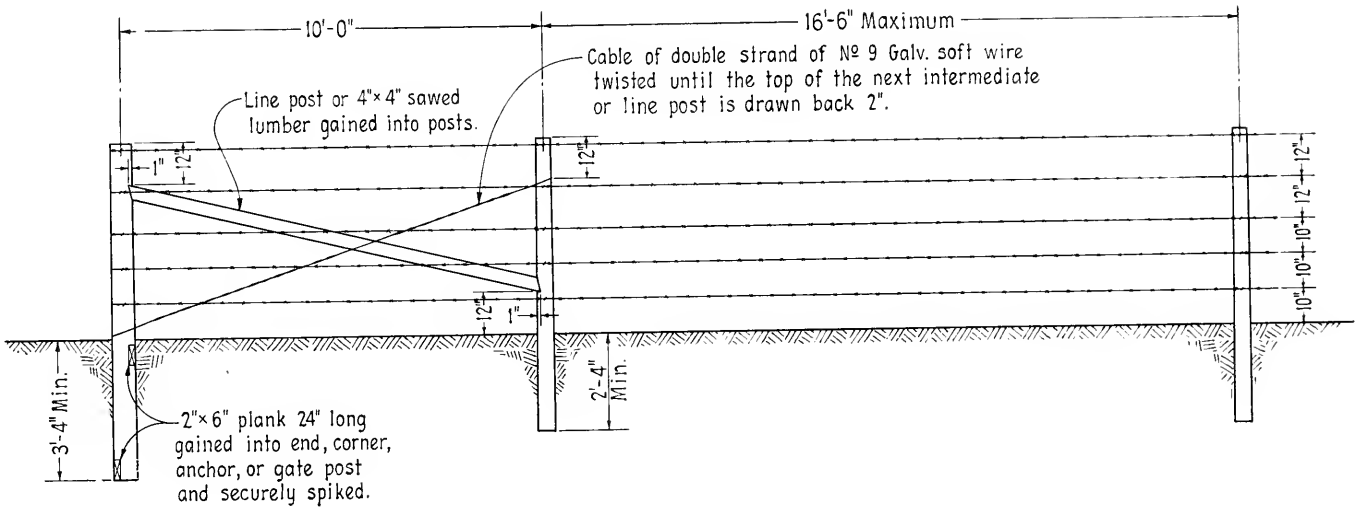
Class "B" fence shall consist of 7 longitudinal smooth galvanized steel wires.
Longitudinal and stay wires shall be Nº 9 gage.
Fence posts may be wood, concrete or metal as specified in this Chapter.

Fig. 2.



Class "C" fence shall consist of woven wire fencing $25\frac{1}{2}$" high with 3 strands of barbed wire above.
The woven wire fencing shall consist of 7 longitudinal, smooth galvanized steel wires.
The longitudinal and stay wires shall be Nº 9 gage.
The spacing of the longitudinal wires, commencing at the bottom, shall be 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5 and $5\frac{1}{2}$ inches.
Fence posts may be wood, concrete or metal as specified in this Chapter.

Fig. 3.



Class "D" fence shall consist of 5 strands of galvanized steel ribbon, smooth round, or barbed wire fencing.
Fence posts may be wood, concrete or metal as specified in this Chapter.

Fig. 4.

Report on Assignment 9

Roadway Signs

(a) Reflectorized and Luminous Roadway Signs, Collaborating with Committees 5 and 9, and the Signal Section, AAR

(b) Develop Standard Close Clearance Warning Sign, Collaborating with Committee 28

J. E. Chubb (chairman, subcommittee), H. Bond, M. B. Davis, J. S. Felton, H. G. Johnson, Paul McKay.

Your committee presents a report this year on Assignment (a) only. It is the final report on the studies that have been carried out in regard to the feasibility of new nuclear light sources. This research has been sponsored by the committee and the Atomic Energy Committee, AAR, and is part of the work of the Research Department, AAR, under the direction of G. M. Magee, director of engineering research, and Rockwell Smith, research engineer roadway. The work was performed by the Armour Research Foundation and is reported on by R. Holtzman and C. A. Stone of that organization.

Feasibility Studies on New Nuclear Light Sources

By R. Holtzman[1] and C. A. Stone[2]

ABSTRACT

A study was made to determine the feasibility of using light sources activated by nuclear radiation. Of the two types of light sources, a conventional light operated by a nuclear battery, and phosphors directly activated by radioisotopes, the former was shown to be impractical at the present time due to the inefficiency and high cost of the possible systems. It was found that the commonly used directly activated phosphors would have light outputs of 10 to 50 times the present values, if they were modified to make them transparent. Unsuccessful attempts were made to produce transparency by compaction of the phosphor powders under high pressure, and it was found that it is possible to grow transparent activated phosphor-type crystals of high radiation resistance. None were available by the time of the conclusion of this work for determination of their luminescent properties under nuclear radiation. The advantages of physically or chemically mixing radioisotopes with the phosphors were examined, but due to the relatively small gain to be achieved, this work was not pursued.

It was felt that because a survey of commercially available nuclear light sources revealed that these sources were not suitable for signs and could be improved for lamp purposes, this work of improvement should be continued further.

A. INTRODUCTION

Among the many applications of radioisotopes which have reached or are approaching practical usage are nuclear light sources. It has long been established that ionizing

[1] Research physicist, Nuclear Physics Section, Armour Research Foundation.
[2] Supervisor, Nuclear Physics Section, Armour Research Foundation.

radiation will generate light in special materials whch have come to be known as phosphors. Only recently, however, have artificially produced radioisotopes become available in sufficient quantities and at a low enough price to consider large-scale use of relatively bright nuclear sources.

The railroad industry has several uses for sources of light which require no external power source, a minimum of servicing and which are not prohibitively expensive. Considerable progress has been made towards providing a signal lamp with these characteristics by commercial firms. Radioactive gas enclosed in a vessel with one transparent end coated with a phosphor comes close to meeting the requirements outlined above. A second problem is the need for self-luminescent signs, and, of course, it would be desirable to improve the characteristics of the aforementioned signal lamps.

The research program discussed in this report has been a study of new approaches to the design of nuclear light sources as well as methods for improving the characteristics of the existing concepts. The program has been pursued with the problems of low-level, self-luminescent signs as the major goal but has not excluded items of interest to nuclear light sources in general, and as a matter of fact the most promising results obtained would appear to be equally important to both applications of interest to railroads.

B. PROBLEMS LIMITING APPLICATION OF NUCLEAR LIGHT SOURCES

Before proceeding with the accomplishments of the research, it is perhaps worthwhile to review the major problems in the development of practical light sources. They can be classed in four interrelated categories.

First is light output. Both the brightness and color of the source must meet minimum standards if the signal or sign is to be of any use. The output is determined by the efficiency of the prosphor and by the maximum amount of energy (radioactivity) which can be effectively used. The efficiency of the phosphor can be subdivided into the intrinsic efficiency, i.e., light output per unit energy loss and the fraction of energy available which is absorbed. The maximum amount of activity is determined by the self-absorption of nuclear radiation in the source material and in some cases by the geometrical relationship of source to phosphor, since the further the separation between source and phosphor, the less the utilization of activity.

Secondly there is the problem of cost. The choice of radioisotope and, therefore, its cost is one parameter and the design and resulting fabrication cost are others. The prices of isotopes have changed and will continue to change over the next few years subject to demand and improvements in methods of production and separation. This means that optimum balance between isotope cost and design cost can change. Nevertheless it is possible to make a choice based on present-day figures.

Closely related to cost is the lifetime of the unit. The half life of the isotope is, of course, one aspect of the problem. Radiation damage is an equally important one since the useful life of the phosphor may be considerably less than that of the isotope itself.

Finally there is the problem of safety. The uncontrolled spread of radioactivity can pose a hazard. The degree of hazard is dependent on the chemical and nuclear character of the isotope, the design of the container and the total amount of activity required.

While this seems like a long list of problems to overcome, it is also a large number of different areas in which to seek improvement. The various topics studied during this program were aimed at overcoming one or more of the problems outlined above.

C. TECHNICAL DISCUSSION

1. Conventional or Electroluminescent Light Powered by Nuclear Battery

The problems in safety can arise from either uncontrolled release of radioactivity or the external radiation hazard. One of the more efficient isotopes, strontium–90 (high energy and high specific activity), would create both hazards if used in curie quantities. It was felt that this might be avoided if a nuclear battery were used to power a light source, since the battery could be buried, minimizing breakage and eliminating external radation.

Nuclear batteries convert the energy of radioactive distintegrations into electrical energy by various means. Five types have been under study at various laboratories.

a. The beta-ray current battery (1)* operates on the principle that the radioactive source deposited on an electrode emits electrons which are collected on a second electrode, creating an electric potential. The voltage of such a battery may be several thousand volts but is limited by the current leakage over the insulators. The useful current is limited by the disintegration rate of the radioactive material. One curie (3.7×10^{10} disintegrations per sec) would produce a current of 6×10^{-9} amp if all the beta particles are collected on the second electrode. In practice the collection may be much less than 10 percent and due to the high voltage a large fraction of the current will be lost through air leakage around the terminals. Finally, as it is desirable to use a plastic insulator between the electrodes, the amount of radioactivity is limited to reduce radiation damage to the plastic. The cell containing one curie of activity, a current of 10^{-10} amp and 1000 v will produce 10^{-7} w. This is an efficiency of 0.02 percent if one uses promethium–47 (maximum power = 420 microwatts/curie). In principle the use of tritium (maximum power = 35 microwatts/curie) would produce a high efficiency on the basis of 1000 v potential and a current of 10^{-10} amp, but due to the self-absorption of the extremely weak betas there will be less power. In practice it is not possible to use a plastic insulator between the electrodes for either of the above two isotopes because this material will stop the betas.

b. A second type of battery is the p–n junction semi-conductor type (2), (3), (4) in which the semi-conductor, silicon or germanium, is irradiated with beta particles. An avalanche of about 200,000 electrons is produced for every strontium-90** beta stopped by the semi-conductor. The efficiency of this cell for visible light is about 6 to 10 percent and for radioactivity about 2 percent at a potential of only about 0.2 v. As the cell function depends on the crystalline structure of the semi-conductor, it is sensitive to radiation damage. A cell irradiated with 50 millicuries of strontium–90 will last only a few weeks.

c. A third type of battery is the contact–potential–difference battery in which a potential of a few volts is produced by two dissimilar electrodes, such as magnesium metal and lead oxide (4), (5), and a current is produced by electrons from a radioactive material, preferably a gas between the plates. The electrons are multiplied by a factor of 200 times for tritium betas, and the potential is about 1.7 v per cell. Tracerlab has built a 70-v battery (open circuit) with a short circuit current of 7×10^{-10} amp with about 1 curie of tritium. This is a power of less than 5×10^{-8} w, giving an efficiency of less than 0.1 percent.

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* Numbers in parenthesis refer to references at end of report.

** In referring to strontium-90 it is always assumed that strontium-90 is accompanied by the 2.2-Mev yttrium-90 daughter.

d. The thermocouple type is powered by heat from a radioactive source (6) (7). In this type a thermopile (a large number of thermocouples in series) was raised to a high temperature by the decay energy of 50 to 150 curies of polonium–210 giving an efficiency of 0.1 to 0.2 percent, respectively, and a power output of 1.8×10^{-3} w and 9×10^{-2} w, respectively, for the two batteries at 1.9 v. The efficiencies given here may be improved one and possibly two orders of magnitude by the use of the newly developed semi-conductor and ceramic thermocouples instead of the previously used metallic thermopiles. Jordan and Birden (6) give the work capacity as 1.8 and 9.2 times that of a RM4Z commercial mercury cell with 30 percent less weight. This means that one may obtain 2 to 10 w–hr out of such a battery. Polonium–210 has only a 138-day half life, so this particular isotope is not practical. One may also use strontium–90 at $10 per curie, with a power output per curie about 0.2 that of the polonium–210, but the half life is 28 years. Another problem is the bremsstrahlung radiation produced by the 2.2-Mev betas of the strontium–90 in that a large amount of radiation shielding may be necessary. In cases where shielding is not an important problem, one may be able to use inexpensive, mixed, raw fission products without much processing. Moreover, with the use of inexpensive radioactive materials it may be possible to produce more powerful batteries up to 24 w (7), which will also operate at high temperatures and with improved efficiencies.

e. Finally, another type of battery that has been constructed is a phosphor layer-photocell type in which a phosphor is radioactivated and current is generated in a photocell exposed to the phosphor. In this way the photocell is protected from radiation damage. In this case radiation damage to the cell is much more serious than that of the phosphor. The efficiency of the system is about 1 percent (a high figure for a nuclear battery) with the use of promethium–147.

Table I shows the various aspects of maximum and expected power conversion of the radiation of radioisotopes which might be useful in nuclear batteries.

With the price of strontium–90 at $10 per curie and promethium–147 at $3.25, the cost of power from these materials is brought into the cost range of the flashlight cell as shown by the comparable data given for a Type D flashlight cell producing about the same power as about 15 curies of strontium–90. This source of power is relatively expensive compared to larger batteries, storage batteries and especially to electric utility power. An example of a battery designed for railroad service is the 2–S–J–1 Carbonaire Battery produced by Thomas A. Edison Industries of Bloomfield, N. J., which, it is claimed, will operate 10 months or more without maintenance at a cost of about $14, or less than $0.01 per w–hr. It must be mentioned here that the costs are not actually comparable in that in the former case only the cost of part of the materials in the power source is considered while in the latter case the finished product is taken as a basis of cost. Hopefully, in large-scale production, the cost of completed nuclear battery may only be a few times the cost of the isotopes.

One of the major difficulties experienced with nuclear batteries is the low energy-conversion efficiency of radioactivity to usable electric power. At present there does not seem to be much probability of increasing the efficiency much above 2 percent. (1) The most efficient type at present is the p–n junction type which is up to 10 percent efficient for light and could be about 8 percent efficient for beta rays, at least in principle, with the use of multiple layer barriers. (4) Very likely its light efficiency will be improved, in which case it may also be improved for conversion of beta-ray energy. The efficiency of the thermocouple battery may be increased somewhat by the produc-

Table I

COST OF POWER FROM RADIOISOTOPES

Radioisotope	Maximum Energy of Radiation (β or α) (Mev)	Average Energy of Radiation (Mev)	Half Life (Yrs.)	Cost/ Curie (Dollars)	Specific Power Micromatts per Curie	Initial Isotope Cost per Micromatt (Dollars)	Cost per Watt-hour (Dollars)	Cost per Watt-hour at 2 per-cent efficiency (Dollars)
Beta Emitters								
Krypton-85	0.69	0.23	10.3	$ 15	1,400	$ 0.011	$ 0.03	$ 4
Tritium	0.018	0.006	12.5	2	35	0.05	0.03	4
Strontium-90[a]	0.55 - 2.2	0.45	28	10	5,300	0.0018	0.012	0.60
Nickel-63	0.067	0.022	85	11,000	130	84.70	1.59	79.50
Carbon-14	0.155	0.052	5,500	22,000	310	.71	2.05	103
Promethium-147[b]	0.223	0.074	2.6	3.25	440	0.0074	0.22	11
				0.50	440	0.0011	0.034	1.70
Alpha Emitters								
Polonium-210	5.3 (α)	5.3	0.38	65	31,000	0.0021	0.086	4
Radium-D[c]	1.19 (β) + 5.3(α)	5.7	22	20,000	34,000	0.59	4.30	275
Strong Gamma Emitters								
Cesium-137	0.56	0.19	30	2	1,100	0.0016	0.004	0.20
Cobalt-60	0.306	0.10	5.3	2	590	0.002	0.06	1.50
Mixed Fission Products	1	0.3	1	1,000	1,800	0.55	43.00	2,150
2-S-J-1 Carbonaire Battery (Nominal capacity 1000 ampere hours)	-	-	0.8 (lifetime)	14.00 (per battery)	400,000 (μ watt power drain)	0.0035	0.01	-

(a). One curie of yttrium-90 (2.2 Mev β) is present for each curie of strontium-90.

(b). Second line figures are based on the assumption that the cost of Pr^{147} will drop to $0.50 per curie.

(c). Radium-E (1.17 Mev β) and -F (5.3 Mev α) accompany radium-D in the amounts of 1 curie each for each curie of radium-D.

tion of larger radioactive sources and better insulation to increase the operating temperature of the hot junction and improved thermocouples.

Most of the batteries are limited in the amount of radioactivity which may be incorporated into them. This is due mainly to lack of resistance to radiation damage breakdown. The main damage is produced in plastic insulators and seals, but this may be corrected by the substitution of glass and mica for plastics. As mentioned earlier, radiation will destroy the p–n junction cell in a short time, but this may be corrected with use of new semi-conductors, although this is just a surmise. Another possibility for present applications is to use low-energy beta emitters such as tritium (0.018 Mev) or promethium–147 (0.223 Mev) so that no radiation damage is produced, as the radiation damage threshold is about 0.3 Mev in theory. Radiation destroys phosphors, plastics, and photocells used in the photo-junction type battery, but again improvement in materials may make it possible to increase outputs and efficiencies.

A step in the use of nuclear batteries is conversion of the electrical energy into light. A method suggested in the proposal for this project is the use of electroluminescence. Other possible methods are the use of fluorescent and other discharge tubes and incandescent lights.

There are two main difficulties in the use of electroluminescence. First, the present efficiency is low so that under the best conditions only about 12 lumens per w is produced. At 100 percent efficiency 1 w should produce 621 lumens at 5560 Angstroms. (8) The efficiency of the electroluminescent device is therefore about 5 percent.

A second problem in the use of electroluminescence is the necessity of alternating current with a frequency of a few hundred cycles per second or higher. The theory of this principle of operation is that the electric field applied to the electroluminescent phosphor may accelerate electrons which knock electrons out of the luminescent centers to produce light. This field then must be reduced to allow electrons to fill the luminescent centers. The rate of variation of this electric field determines the rate of filling and emptying the luminescent centers, and the efficiency of the device increases with frequency up to the point where the electrons cannot empty the luminescent centers rapidly enough to take advantage of the high frequency. This would involve a device to convert the direct current of battery to alternating current. At the low powers possible with nuclear batteries this device would have a maximum conversion efficiency of 90 percent and would probably involve a mechanical device. If one assumes an efficiency 2 times the present maximum, namely 10 percent, for electroluminescence, a 90 percent efficiency for the conversion of direct current to alternating current and an efficiency of 8 percent for a nuclear battery (a high efficiency for the near future) (1), then the over-all efficiency is the product of the three efficiencies or 0.7 percent conversion of radioactive decay energy into light.

A nuclear battery with suitable characteristics of voltage and current could operate light sources other than electroluminescent. The efficiency of fluorescent light (9) ranges up to about 12.5 percent for 40-w tubes and probably one may obtain very low-powered fluorescent lights. Similarly, the efficiency of incandescent lights ranges from 1 to 5 percent, with the efficiency an increasing function of the power consumption. Therefore, a low-powered light bulb may have appreciably less than 1 percent efficiency. Gas discharge tubes such as mercury are somewhat less efficient than the fluorescent lights for the production of visible light, so these would probably not be useful.

If one is able to construct a suitable fluorescent light with a 10 percent efficiency and a battery with 8 percent efficiency, the over-all efficiency would be 0.8 percent. Other presently known electrically operated light sources would be less efficient.

It is concluded that nuclear batteries as a power source for light production make inefficient use of the radioactive decay energy compared to the presently known radio-activated light sources which attain efficiencies of about 10 percent. (10), (11) The maximum efficiency obtainable from a nuclear battery is 2 percent at present (1) and possibly 8 percent (4), and there are some limitations on the maximum power. The advantage of a battery over a directly excited light source is that the large amount of radioactive material may be easily shielded by burying or covering the battery with building materials, while an exposed source would be difficult to shield and would constitute a health hazard. In the future, if the prices of radioisotopes are further reduced, a battery-light system might be more economical and desirable in spite of low overall efficiency.

D. INCREASED EFFICIENCY UTILIZING LARGE TRANSPARENT PHOSPHORS

One approach to more practical light sources is the increased utilization of the radiation energy. It is well known that the powdered phosphors currently used do not effectively use the energy available from high-energy beta particles. The efficiency can be improved if a stable and transparent phosphor of reasonable thickness can be made.

A comparison was made of the relative efficiencies in light output of radio-activated phosphors in the transparent and powdered forms per beta particle. Four types of phosphors were studied. The first was copper-activated zinc sulfide, a representative of the usual and inherently most efficient type of phosphor. This type will produce the most light in a thin film per unit energy loss in the film, and the resistance to radiation damage is fairly good. This type of phosphor generally is a non-transparent powder.

A second type of phosphor is the alkali halide type, such as sodium iodide containing a small amount of thallium activator. These materials have been developed as scintillators for nuclear particle detection at low radiation levels. As a result, the luminescent properties for constant light production and radiation resistance are not well known. These materials are transparent, but the intrinsic luminescent efficiency of these materials is about half that of zinc sulfide. As a result of having been developed as scintillators in which the peak of the light output spectrum must match the sensitivity of a photomultiplier tube, little has been done to produce scintilators with spectral outputs near 5200 Angstroms, the peak sensitivity of the scotopic (dark-adapted) eye. This reduces the efficiency for viewing by eye 15 to 50 percent, depending on the wavelength and the efficiency of possible wavelength shifters.

A third type of phosphor is the organic crystal represented by anthracene, the most efficient one known. Usually these materials must be highly purified to produce a light output efficiency one-half that of sodium iodide, and there is a similar problem of the spectral-emission peak. The organic phosphors may, however, be somewhat less expensive than inorganic crystals.

A fourth type is the polystyrene plastic scintillator incorporating various wavelength shifters to change the spectral output to a useful wavelength. While the efficiencies of these scintillators are somewhat less than that of anthracene (peak heights of 50 to 80 percent that of anthracene), these are even less expensive to produce and fabricate than the crystalline organic scintillators.

Several types of phosphors were chosen for study in that any of them may turn out to be unsuitable for some reason, such as radiation damage which destroys the luminescent properties. For example, the polystyrene might be better than anthracene

in that radiation damage even by ultraviolet light is known to reduce the scintillation properties of anthracene. (12).

The relative light outputs of the four representative phosphors are shown in Table II. It is assumed that the zinc sulfide powder obeys Lambert's law for the absorption of its own emitted radiation, that is, the decrease in intensity with distance is proportional to the intensity. The exciting radiation is absorbed exponentially by the phosphor for a radiation source behind the phosphor. The derivation of the equation for the light output of the phosphor is as follows:

$$\frac{dL(x)}{dx} = \lambda I(x) - \epsilon L(x)$$

$$I = I_o e^{-\mu x}$$

$$\frac{dL(x)}{dx} = \lambda I_o e^{-\mu x} - \epsilon L(x)$$

integrating

$$L(x) = \frac{\lambda I_o}{\epsilon - \mu} e^{-\mu x} + Ce^{-\epsilon x}$$

$$\text{at } x = 0,\ L(0) = 0$$

so that

$$C = \frac{-\lambda I_o}{\epsilon - \mu}$$

and

$$L(x)/I_o = \frac{\lambda}{\epsilon - \mu} (e^{-\mu x} - e^{-\epsilon x})$$

where

$L(x)$ = light output
x = distance in phosphor
λ = conversion efficiency of exciting radiation into light (light energy/cm)
$I(x)$ = intensity of exciting radiation as a function of x
I_o = intensity of exciting radiation at $x = 0$
μ = absorption coefficient of the exciting radiation in the phosphor
ϵ = absorption coefficient of the emitted radiation in the phosphor.

The efficiency of the phosphor for conversion of the exciting radiation into light is thus λ/μ, the fraction of energy converted to light. The unit of x is in mg/cm^2, as this is easier to determine in a powder and it is the unit used in beta-ray absorption data. I and $L(x)$ are in the same energy units. μ is the absorption coefficient for beta rays in cm^2/gm determined from the beta-particle range data using the assumption that half the beta particles are stopped in 1/5 the effective range of the particles. (13). This figure, which tends to weight the light output in favor of transparent phosphors, is reasonable but may be as low as 1/10. The derived formula assumes that the intensity of beta particles through the phosphor decreases exponentially, which is a good approximation up to one-half the range. At least 80 percent of the beta particles are stopped in this thickness. As a corollary to this one may use a phosphor thickness one-half the range of the beta particles with little loss in light output in the transparent phosphors.

The value of ϵ is based on a half thickness of 20 mg/cm^2 and an example is given for 10 mg/cm^2. The values obtained from various data in Leverenz (14) give 2 to

Table II

RELATIVE LIGHT OUTPUT OF VARIOUS PHOSPHORS

Phosphor	Half Thickness for Light Absorption (mg/cm^2)	Efficiency of Phosphor (Percent)	Phosphor Thickness (mg/cm^2)	Phosphor Thickness (mm)	Relative Light Output from Pm^{147} Activation ($L/I_o \times 10^3$)	Relative Light Output from $Sr^{90} - Y^{90}$ Activation ($L/I_o \times 10^3$)	Factor to Convert Light to 5200Å	Correction to 5200Å Light Output (Pm^{147}) ($L/I_o \times 10^3$)	Correction to 5200Å Light Output ($Sr^{90}-Y^{90}$) ($L/I_o \times 10^3$)
ZnS(Cu) = 4.1 gm/cm^3	20	12	10	0.02	3.2	-	1.0	3.2	-
			15	0.04	3.9	-	1.0	3.9	-
			20	0.05	4.1	-	1.0	4.1	-
			30	0.07	3.9	-	1.0	3.9	-
			40	0.10	3.4	10.7	1.0	3.4	10.7
			50	0.12	-	11.1	1.0	-	11.1
			60	0.15	-	11.0	1.0	-	11.0
			70	0.17	-	10.5	1.0	-	10.5
ZnS	10	12	10	0.02	0.66	-	1.0	0.66	-
	10		30	0.07	-	7	1.0	-	7
ZnS (Transparent Xtal)	1000	12	60	0.15	8.9	-	1.0	8.9	-
			1000	2.4	-	10.5	1.0	8.9	105
NaI(Tl) = 3.66 gm/cm^3	1000	6	60	0.16	4.5	-	0.79	3.6	-
			1000	2.7	-	53	0.79	-	42
Anthracene = 1.25 gm/cm^3	1000	3	60	0.5	2.2	-	0.86	1.9	-
			1000	8.0	-	27	0.86	-	23
Polystyrene = 1.0 gm/cm^3	1000	1-1/2	60	0.6	1.1	-	0.86	0.95	-
			1000	10.0	-	14	0.86	-	12

30 mg/cm^2 for the half thickness, although this value may be as much as 50 mg/cm^2 in some cases. The half thickness for the transparent materials is large compared to the maximum thickness of material involved (1000 mg/cm^2).

The values taken for the beta particle range were those obtained for the range in aluminum. (15) These values depend on A/Z, the atomic mass number divided by the atomic number, which for aluminum and for zinc sulfide, are essentially the same. The efficiency of the phosphors for production of light is shown in Table II. (16). The relative values of the efficiencies are fairly good, but they may vary $\pm$ 25 percent in practice due to the particular samples of phosphors used and geometry. The absolute values are not reliable, as shown by the absolute efficiency of anthracene which varies from 3 to 10 percent, depending on the particular experimenter.

An additional efficiency correction is made to compensate for the spectral emission of the phosphor. The efficiency of a phosphor is stated as the emission energy of light divided by the excitation energy. The light output may be at the very blue end of the spectrum with a high energy per quantum, so that conversion to light at 5200 Angstroms produces an energy loss in that the wavelength is shifted quantum for quantum rather than energy for energy. Table III gives the efficiency factor to convert the peak emission to emission at 5200 Angstroms. The conversion factor for the efficiency without the use of a wavelength shifter taking account of the sensitivity of the scotopic eye is shown in the last column in Table III.

Table II shows that if weak beta emitters are to be used to produce the exciting radiation, there is a gain of two in the use of transparent zinc sulfide, but no advantage in the use of other phosphors. If high energy beta emitters are used, a transparent zinc sulfide phosphor 2.4 mm thick has a gain of 10 over the powder of transparent phosphor activated by promethium–147 and a gain of 30 over a promethium-activated powder. There is a gain of 2 to 4 in the use of sodium iodide or anthracene over the powder

Table III

CORRECTION FACTOR TO CONVERT EMISSION PEAK LIGHT OF PHOSPHOR TO PEAK AT 5200Å

Phosphor	Emission Peak (Å)	Efficiency Factor for Wavelength Shifter	Conversion Factor Without Wavelength Shifter (Sensitivity of Scotopic Eye at Emission Peak)
ZnS(Cu)	5200	1.00	1.00
NaI(Tl)	4100	0.79	0.35
Anthracene	4500	0.86	0.45
Polystyrene	4500	0.86	0.45

if high-energy beta emitters are used. If it is assumed that the absorption of emitted light in the phosphor has a half thickness of 10 mg/cm^2, then a transparent phosphor has an additional advantage of a factor of about 6 for the use of a weak beta emitter and a gain of 1½ in the use of strontium–90.

As a result of this data an attempt was made to produce transparent zinc sulfide by compaction of the powder. This method has long been used to produce transparent potassium bromide windows for use in infrared spectrometers, and it is known that other alkali halides may be so compressed. Alkali-halide phosphors have been produced in this laboratory. It was thought that a similar process might occur in the compaction of zinc sulfide.

In order to test this hypothesis attempts were made to compress zinc sulfide powders and phosphors employing the alkali–halide techniques. This consists of evacuating the air from the sample and compressing it at 180,000 psi. This produced a pellet with a shiny surface but no appreciable transparency was observable. Subsequently, a small compaction die was used and the pressure raised to about 430,000 psi, but no improvement in transparency was observed. Moreover, upon compression the color of the phosphor powder changed from white to brown, and the luminescent properties were destroyed. Similar results were obtained with a zinc sulfide–cadmium sulfide phosphor obtained from the General Electric Company. In this case, besides losing luminescence, the phosphor changed from green to brown and no transparency was observed.

We then tried a mixture of the phosphor and potassium iodide. The latter material was chosen as one which is compactible into a transparent luminescent mass and one with which this laboratory had had experience. A mixture of 50 percent potassium iodide and 50 percent of the phosphor was made up, mixed thoroughly and then compacted. Several phosphors were used—a zinc sulfide phosphor from the Radio Corporation of America, a similar one from the Sampson Chemical and Pigment Company in Chicago and a zinc silicate phosphor from the latter company. The compacts, about 1 mm thick, showed very little light transmission (1 to 2 percent) when made with zinc sulfide and potassium iodide. The zinc silicate was essentially opaque, due probably to the fact the phosphor grains themselves are opaque. The zinc sulfide phosphors may be transparent, and the lack of transparency of films of the powder is due to light scattering by the small particles. Measurements with a spectrophotometer showed the compact to have an optical density about 25 percent that of a film with an equal amount of zinc sulfide. This indicates that while the transparency is small, there may be an appreciable improvement in the use of the compact.

W. Metcalf of the Eagle–Picher Company was contacted and the possibility of obtaining large crystals of a phosphor was discussed. This company has been growing large crystals of cadmium sulfide for use in semi-conductor studies which are available on a commercial basis. It has also grown large clear zinc sulfide and zinc sulfide–cadmium sulfide crystals. Both of these materials in the powder form are good phosphors under beta-ray excitation. It is also possible to "dope" these large crystals with other materials so that they would have the same chemical composition as the phosphors.

In order to determine the feasibility of using a "doped" single crystal, several cadmium sulfide crystals with 0.05 percent silver, which were readily available, were obtained. These are fairly transparent and do luminesce, under X-ray excitation, with a reddish color, the characteristic color of a cadmium sulfide–silver phosphor. These are not very active, but they are heavily "doped" compared to phosphor powders and much less transparent than the pure crystals. Both factors may reduce light output.

No scintillation properties were observable as the excitation sources are weak and the photomultiplier tubes used are insensitive at the red end of the spectrum. It was felt that sufficient success has been obtained with visual observations under X-ray excitation to pursue the zinc sulfide crystals.

One does not know how well "doped" zinc sulfide crystals will work, since there has been little study of them as phosphors. Some information is known from the work of Tomlinson (17) who grew single zinc sulfide crystals and activated them with copper and chlorine. These crystals were luminescent under ultraviolet excitation and in the presence of an electric field (electroluminescence) but their action under high energy beta and X-ray excitation is not known.

Several large "doped" crystals were ordered at this juncture so that measurements on light yield and transmission could be made. These are not routine production items, and Eagle-Picher was unable to supply any phosphors prior to completion of the program.

During the period in which we were awaiting delivery, measurements on other powder phosphors were continued. A crystal of thallium-activated potassium iodide which has total light output about the same as that of sodium iodide was used as a standard phosphor. Various silver-activated zinc sulfide and zinc sulfide–cadmium sulfide phosphors were made into thin films of various thicknesses on a glass slide. These were produced by evaporating an alcoholic slurry of the phosphor powder on a known area of a glass microscope slide. By weighing the slide before and after adding the powder, the film thickness can be determined.

The phosphors, excited by a radioactive beta emitting source, were placed on a photomultiplier tube and the current from this tube was measured. This current is proportional to the light output of the phosphor. The detector used was about equally sensitive to all the wavelengths of light emitted from the various phosphors. Table IV shows the results of this work.

This table shows that, when activated by strontium–90 betas, the transparent potassium iodide phosphor produces about 25 times the light output of the best of the phosphors available from the General Electric Company, and even when the sensitivity of the eye is taken into account there is still a factor of 20 between the powder and transparent crystal. If an isotope emitting a weaker beta is used this ratio will decrease, probably to about 5 if krypton–85 is used.

The film thicknesses used here were about 7 mg/cm^2 for maximum light output of the powder phosphors. This is to be compared to the calculated maximum of approximately 50 mg/cm^2. The difference is probably due to the fact that the coefficient of light transmission was assumed to be too large. Moreover, as this coefficient appears in an exponential function, the thickness is very sensitive to this value.

A difficulty in these measurements was that most of these phosphors are excited to emit light long after exposure to visible light. This excitation decays in a few minutes to many hours, depending on the phosphor. The previously seen unreasonable results (efficiencies were greater than 100 percent, etc.) were due to this phenomenon. This was eliminated by setting up the instrument in a minimum of light, allowing the light emission to decay away and by using a more intense source to make the light excitation effects negligible.

Two samples of its best phosphors were obtained from U. S. Radium Corporation. One, 852A, emitting in the blue and the other, Y–240, emitting in the yellow regions of the spectrum. The results are listed in Table V.

Table IV

RELATIVE LIGHT OUTPUT OF PHOSPHORS

Phosphor	Radioactive Source	Current (Amperes)	Ratio to KI(Tl) Value
Potassium Iodide Thallium-Activated	Sr^{90}	245×10^{-9}	1
Zinc Sulfide Silver-Activated	Sr^{90}	2.8×10^{-9}	1/88
Zinc Sulfide-Cadmium Sulfide Copper-Activated	Sr^{90}	9.7×10^{-9}	1/25
Cadmium Sulfide Crystal Silver-Activated	Sr^{90}	0.78×10^{-9} (background)	0
Compact: 50 percent KI(Tl) (ZnCd)S:Cu	Sr^{90}	7.3×10^{-9}	1/30

TABLE V—LIGHT OF PHOSPHORS

Phosphor	*DC Current Photomultiplier Tube (Amperes)*	*Light-Output Relative to KI (Tl)*
KI (Tl) (Crystal)	245×10^{-9}	1.00
852A	2.9×10^{-9}	1/83
Y-240	5.9×10^{-9}	1/42

These data confirm the conclusion that the best powder phosphors are inferior in light output to the intrinsically less efficient transparent potassium iodide crystals.

E. ADDITION OF RADIOISOTOPES TO PHOSPHOR

One problem involved in the use of radioactivated phosphors as light sources is to determine the optimum method of relating the radioactivity to the phosphor. The simplest method would be to produce separate phosphors and radioactive sources, then if the source becomes weak or the phosphor loses efficiency only one of these need be replaced. It may also be difficult to combine the source into the phosphor due to the effect of impurities on the luminescent properties of phosphors. However, due to the cost of the radioisotopes and to safety considerations, it may be necessary to keep the radioactivity to a minimum so that a separate source may be undesirable.

It has been suggested that the efficiency of a phosphor–radioisotope combination may be improved by mixing the radioisotope directly with the phosphor, possibly by chemical combination with the phosphor. Chemical combination would possess several advantages over a separate source and phosphor or physical mixing.

a. In the case where very weak beta emitters, such as tritium, are used only radioactive atoms and phosphor would be present. This would reduce the non-light-producing absorption of the beta particles.

b. If an organic phosphor is used, tritium may be easily incorporated into the phosphor. Moreover, an extraneous, non-luminescent material might even quench the luminescence of the phosphor.

c. A source made up of radioactive material over which a phosphor is placed may have a large amount of self-absorption and backscattering due to surrounding materials which will reduce the available radiation. The seriousness of this problem may be greatly reduced by mixing the radioactive materials with the phosphor or using a thin transparent beta source with phosphor on both sides.

d. Mixing may produce a non-transparent material, thereby greatly reducing its efficiency while it may be possible to incorporate the radioisotopes directly into the transparent phosphor without quenching its luminescence.

e. Another problem is that radioisotopes are usually not pure radioisotopes but contain extraneous material, much of which may be chemically the same as the radioisotopes. In this case it may be profitable to incorporate this directly into a phosphor to reduce non-light-producing self-absorption of the betas in the phosphor. In case a large concentration of pure radioisotopes is needed, there may be an appreciable amount of the radioisotopes present, and efficiency might be improved if this were part of the phosphor.

f. It may be safer to incorporate the radioisotope into the phosphor in case the sign is broken. There will be little advantage to this unless the radioisotope is in powder form and the phosphor in large crystals. In this case there would be somewhat less probability of spreading radioactive contamination. Also, it would be possible to use safer low energy isotopes. An example is strontium–90 versus tritium; the maximum permissible limit of strontium–90 in the body is 1 microcurie while that of tritium is 10^4 microcuries. (18) While the ratio of the power of strontium–90 to that of tritium is 150, even 150 curies of tritium is still safer by a factor of 65 than 1 curie of strontium–90. Even promethium–147 is 10 times safer than strontium–90 per unit of power.

The disadvantages to chemical incorporation of the radioisotopes are the following:

a. The gain in efficiency, except in particular cases, will be small and in case of mixing a small (several curies/gm) amount of radioisotopes with a powder will be negligible.

b. Phosphors are difficult to produce, the conditions of mixing are critical and there is danger of radioactive contamination spreading when the materials are heated and mixed. Also, it may be necessary to purify and crystallize the radioactive phosphors.

c. It is much more costly to handle radioactive materials than nonradioactive ones of the same type.

d. The safety advantages are not great as the radioactive material may be fixed in a binder, and in an accident powder may be formed in any case.

e. There is little advantage to low-energy beta emitters except from the point of view of safety and in thin film phosphors where the beta energy could be used efficiently. The total power per curie of strontium–90 is such that over 150 curies of tritium would be needed to equal it, if it is assumed that there is equal efficiency for the conversion of radioactive energy into light. The efficiency of some inorganic phosphors varies in the low-energy region such that at 6 kev (average energy of tritium betas) beta energy the luminescent efficiency is directly proportional to the voltage. (19) There are some losses due to the bremsstrahlung radiation emitted by the high energy

yttrium–90 betas, but these are small. In this case the bremsstrahlung may produce problems in shielding of the radioactivity, though.

This survey shows that there is little advantage at present to binding the radioisotope into the phosphor by chemical means, unless it is found that tritium should be used. Any gain would probably be less than 50 percent as compared to the use of transparent phosphors which, if successful, would produce a gain of at least an order of magnitude in light output.

F. COMMERCIAL LIGHT SOURCES

1. New England Nuclear Corporation

One light source commercially available was investigated and the characteristics were determined in a conversation with Dr. E. Shapiro of the New England Nuclear Corporation, which produces the Atomlight. This device is a phosphor-coated glass container filled with tritium gas to sub-atmospheric pressure and sealed off. The container is then encapsulated in an aluminum or brass holder and covered with a Plexiglass window to protect the container. For added safety the window may also be sealed with an O-ring to prevent the escape of tritium in case of glass container breakage.

The light output varies from 15 microlamberts to about 600 microlamberts, depending on the source size. The latter-size source is a 1.15 in diameter light source observable at 100 ft in twilight. Increased tritium pressure did not improve the light output because of the energy loss due to the self-absorption of the betas in the gas, but some added light output may be obtained with the use of a spherical container. This gas-filled source is more or less temperature independent between — 186 deg C and + 100 deg C where the light measurements were obtained only qualitatively at the temperature extremes. A similar light source using chemically bound tritium in the phosphor gave no light output at the above temperature extremes.

The average energy of the betas emitted by tritium is 6 kev and the maximum energy is 18 kev. Consequently, while as much as 3 curies of tritium is used, only a few counts per minute of x-radiation penetrates the walls of the source. The stability was good, and in tests conducted over one year the decrease in light levels was that due only to the radioactivity decay of the tritium.

The approximate cost of the light sources is: NEL 1—$100, NEL 2—$80 and NEL 3—$145. NEL 1 and NEL 3 are the same 1.15 in diameter, except that NEL 3 has the O-ring construction. NEL 2 is of slightly smaller size. These sources are available only in blue, green and red. Other colors were found to have low light output or were unstable.

The cost of this light source apparently depends mainly on labor so that mass production could greatly decrease the cost.

The source might be useful as a marker and could possibly be modified for low-level sign illumination.

2. United States Radium Corporation

The United States Radium Corporation produces various types of radioactivated light sources with intensities up to 1000 microlamberts. Their sources use krypton–85, strontium–90 and tritium with various types of zinc sulfide phosphors which are stable in the sources up to 100 microlamberts, but which are damaged at the higher intensities.

This damage may be due to radiation deterioration of the organic materials in the sources.

The high brightness sources are gas-filled Kr^{85} sources similar to the Atomlight, while other sources use Sr^{90} mixed with phosphor.

The cost of this high brightness source varies from about $50 per unit for 250 unit lots to about $125 for a single unit, and prices on other types of sources would depend on the source type and construction. This source is visible for over 500 yd in twilight and the phosphor intensity may vary from ± 5 to ± 25 percent for extremes of outdoor temperatures, depending on the type of phosphor used.

The tritium type, used for small signs, is bright enough that it may be seen in the dark by a person whose eyes are light adapted. The surface brightness of a sign containing 2 curies of tritium is about 100 microlamberts, close to the maximum obtainable. The sign had 2 lines 6 in long of ½-in letters and was of very simple construction. Two grooves were milled in a plastic block and this was sealed with an opaque plastic sheet containing transparent letters backed by a phosphor. A large sign similar to this could be made, although it would be fairly expensive and of limited light output.

Signs using krypton–85 could be made, but as this isotope has a higher decay energy, radiation damage and escape of the gas may be a problem, so that in such a sign it may be necessary to use more expensive glass or glass and metal construction. Mr. Taylor was not very hopeful about the economics of such a sign.

G. CONCLUSION

The studies and experiments performed during this program have thus lead to a series of conclusions concerning the ideas which were initially suggested as possible means for improving nuclear light sources.

Conventional lights powered by a nuclear battery do not appear to represent a sufficiently great improvement to warrant further consideration and effort. This approach would permit enclosure of the radioactivity in a very durable housing which ultimately could be buried. This would, of course, virtually eliminate the safety problem. However, even the most optimistic prices for isotopes lead us to conclude that the cost per unit power would be 10 times as great as a conventional battery supply. We have not taken into account the reduced maintenance by virtue of the expected long life, but it does seem doubtful to us that even maintenance costs could overcome this large differential. Equally important is the fact that, in spite of a fair amount of research, no one has yet succeeded in making the comparatively high-powered nuclear battery that would be required. It is possible, however, that with the emphasis being placed on long-lived power supplies for space research, a solution may be forthcoming in the next few years. We would not recommend that the railroads pursue this approach for the time being.

The most promising approach for an improvement on existing sources, and therefore a closer approach to practicality, lies in the use of thick, clear, high-efficiency phosphors. As was indicated in Section D, gains of from 10 to 50 in light output can possibly be achieved. This represents, we feel, sufficient potential to warrant further investigation. This approach is not without its problems. Radiation damage represents a large hurdle. As was pointed out, zinc sulfide represents the best possibility for avoiding radiation damage, but the technology of growing large "doped" crystals is still in its infancy. Therefore, a program to continue this line of investigation should pursue at least two avenues—the production of zinc sulfide phosphors and the search for other phosphors which have high efficiency and radiation resistance.

After considering the pros and cons of adding the radioactivity to the phosphor by either chemical or physical means, we conclude that this offers no great improvement, with the possible exception of the isotope tritium. For high energy (greater than 100 kev) beta emitters, the only gain is a slight increase in efficiency through better source-to-phosphor geometry. The cost and difficulty of combining the two materials would seem to negate any increased efficiency available. In the case of tritium, a factor of 10 improvement is possible if the tritium is added chemically to an organic phosphor. In such a case, however, the question of radiation damage reappears. On this basis it would seem inadvisable to pursue this approach also.

We briefly mentioned in a letter, towards the end of the project, the possibility of a new technique being of advantage for nuclear light sources. This represents the use of clathrate compounds which can hold foreign molecules much in the fashion of a sponge without changing the properties of the clathrate itself. Two possibilities are evident. If a phosphor can be found with clathrate properties, then the inclusion of radioactivity might be a simple and straightforward process. In the case of krypton, it is conceivable that instead of a gas-tight vessel a clathrate could be used to contain the activity thus reducing the complexity and cost.

In summary, we would recommend a continuing program to further investigate the problem of large and efficient phosphors and to examine the characteristics and advantages of clathrates as applied to nuclear light sources.

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Report on Assignment 10

Ballast

(a) Tests

(c) Special types of ballast

(d) Specifications for sub-ballast

R. H. Beeder (chairman, subcommittee), E. W. Bauman, J. G. Campbell, J. P. Datesman, A. T. Goldbeck, E. W. McCuskey, R. L. McDaniel, J. W. Thomas, Stanton Walker, C. E. Webb.

Your committee reports this year on two of its three assignments, namely, (a) Tests, and (c) Special Types of Ballast. In addition, the committee submits recommendations for revision of Specifications for Prepared Stone, Slag and Gravel Ballast.

The report on Assignment (a) is presented as information and is a progress report on ballast tests being carried on at the Association of American Railroads Research Center.

The report on Assignment (c) is also submitted as information and is a progress report of the activities of the joint committee representing the AREA and the Asphalt Institute on asphalt ballast treatment.

Manual Recommendations

Gravel in many areas is produced from large oversize material in which substantially all particles are crushed and which is, therefore, essentially a crushed stone. In order to classify crushed gravel ballast as crushed stone and give it the same gradation requirements as recommended for crushed stone and crushed air-cooled blast furnace slag ballast, your committee submits the following recommendations for adoption and publication in the Manual.

Pages 1–2–2 to 1–2–4, incl.

SPECIFICATIONS FOR PREPARED STONE, SLAG AND GRAVEL BALLAST

Page 1–2–3: Under the table in Art. 4 (b), change the present "Note:" to read "Note 1:"

Add the following as a second note under this table.

"Note 2: Gravel meeting these requirements for grading and having not less than 75 percent crushed particles with two or more fractured faces and not more than 5 percent of uncrushed particles shall be considered as crushed stone."

In the table under Art. 4 (c) change the Percent Crushed Particles for G–3 gravel ballast to read 41–75 instead of 41–100.

Report on Assignment 10 (a)

Ballast Tests

This is a report on the ballast tests in progress at the AAR Research Center.

The research is sponsored by Committee 1 and is under the general direction of G. M. Magee, director of engineering research, and Rockwell Smith, research engineer roadway. It is supervised and reported by G. L. Hinueber, assistant research engineer roadway.

Previously, results on 17 ballasts tested with the oscillator equipment were reported. Recently, new dynamic test equipment consisting of an Amsler Pulsator and hydraulic jacks were received and installed in the AAR Engineering Laboratory. This equipment is being utilized for repeated-loading tests on ballast as described in the AREA Proceedings, Vol. 59, 1958, page 818. Figs. 1 and 2 are two views of the new ballast test equipment in operation showing the loading frame, pulsator, hydraulic jacks, and the ballast test sections.

The test program is not far enough advanced as yet to report data or results or to draw any conclusions. It is expected that a fairly comprehensive report on test results will be presented next year.

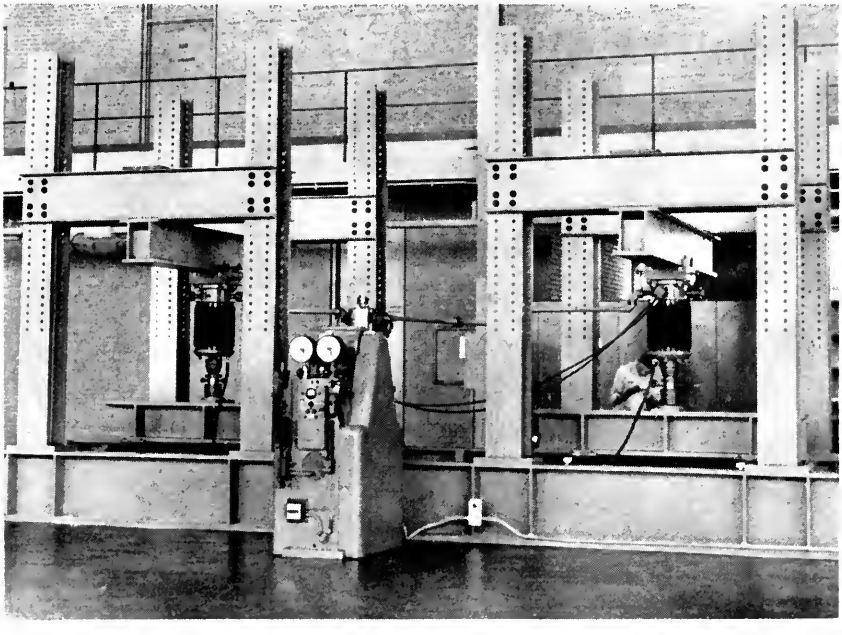


Fig. 1.

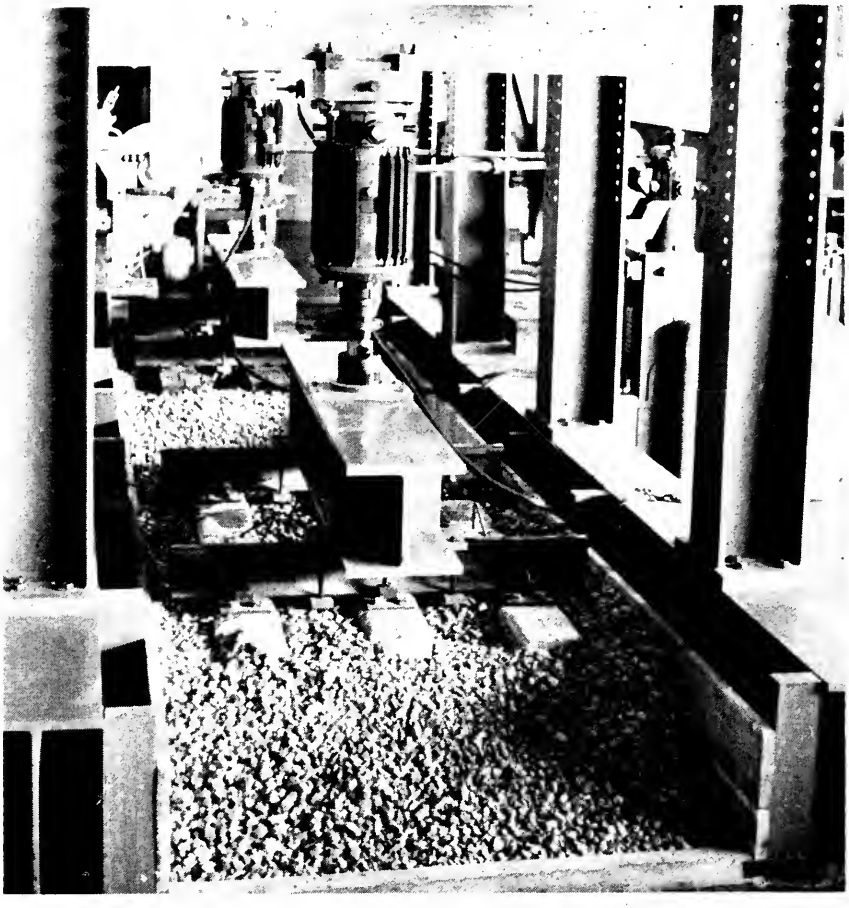


Fig. 2.

Report on Assignment 10 (c)

Special Types of Ballast

Under committee sponsorship the Research Department, AAR, has entered into a cooperative agreement with the Asphalt Institute for the study of the methods and economies involved in the treatment of ballast sections with asphaltic materials. A program involving approximately 31 miles with an equivalent length of untreated check sections has been projected for 1959 application, ranging geographically from Illinois to California, and including crushed limestone, blast furnace slag, chat and volcanic cinder ballast.

Specially equipped cars have been completed to facilitate the spraying of hot asphalts and the spreading of a chip or screening cover coat or seal as may be required

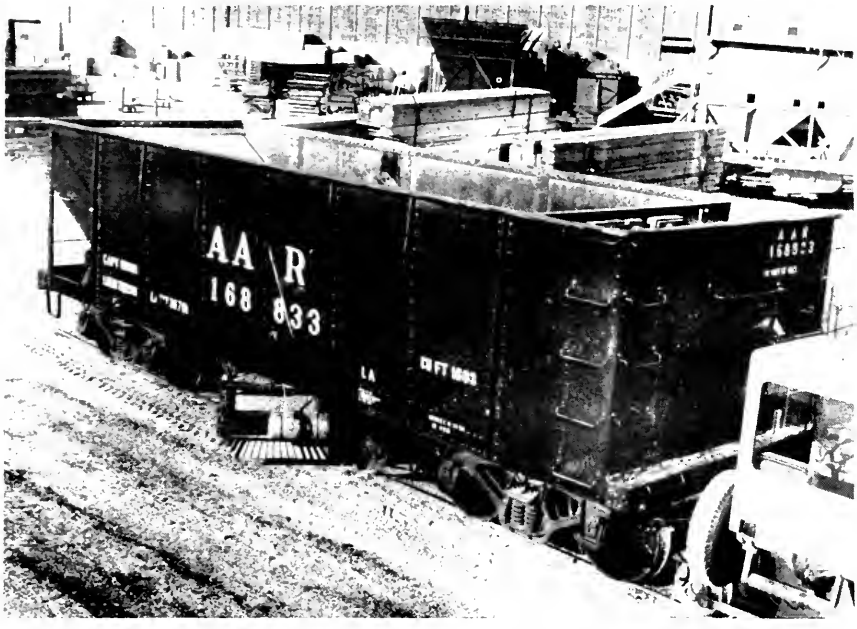
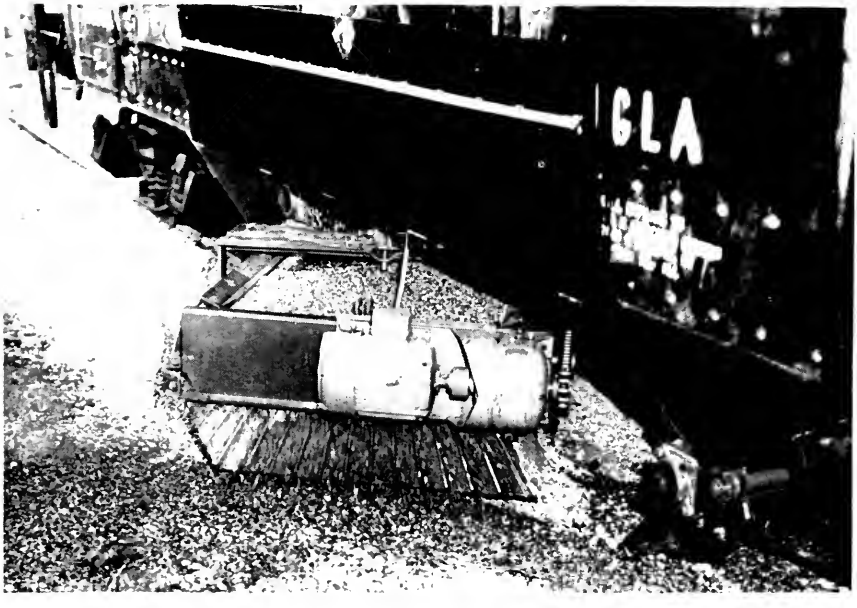


Fig. 1—Specially equipped hopper car developed by the Barber-Green Company.



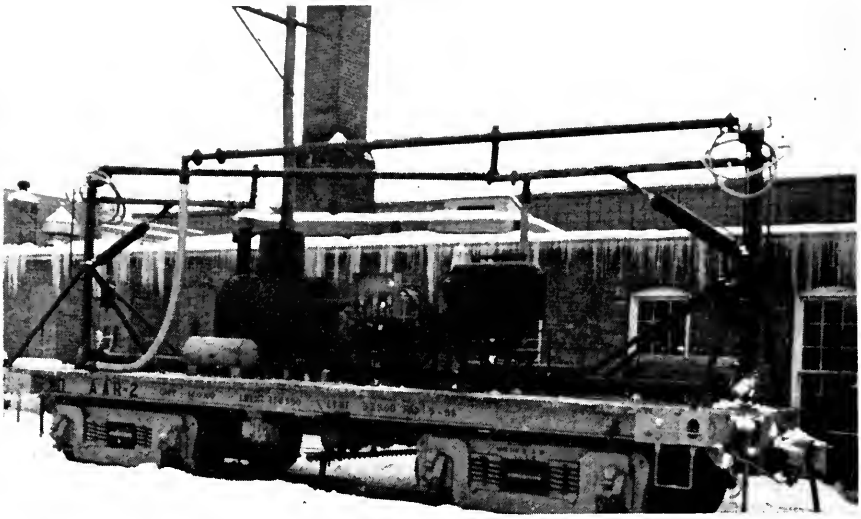


Fig. 2—Partially completed asphalt distributor car developed by the E. D. Etnyre Company.

following the ballast penetration application. Fig. 2 shows the partially completed asphalt distributor car developed by the E. D. Etnyre Company, Oregon, Ill., and Fig. 1 shows the specially equipped hopper car developed by the Barber–Greene Company, Aurora, Ill.

This report is submitted as information.

Report on Assignment 11

Chemical Control of Vegetation

Collaborating with Signal Section and Communications Section, AAR

C. E. Webb (chairman, subcommittee), C. R. Bergman, P. G. Martin, S. J. Owens, A. J. Pacelli, A. C. Parker, Jr., W. F. Petteys, W. O. Trieschman.

The report on this assignment, presented as information, consists of four parts. Part 1 is a report on vegetation-control research at Iowa State College under its cooperative agreement with the Engineering Division, AAR. This is the final report on the work at that institution. Part 2 is a similar report of the work at North Carolina State College, which will be continued through 1959. Part 3 is the report of the AAR research staff on the field studies conducted in 1958, and Part 4 is a discussion of the probable costs involved in the development of a new herbicide.

Parts 1 and 2 were prepared by staff members of the colleges, as indicated. Parts 3 and 4 were prepared by C. G. Parris, agronomist, and Rockwell Smith, research engineer roadway, of the AAR research staff. The work has been conducted under committee sponsorship as part of the work of the Research Department, AAR, under the direction of G. M. Magee, director of engineering research, and the supervision of Rockwell Smith.

Part 1—Vegetation Control on Iowa Roadbeds—1958

By W. E. Loomis, W. M. Struve, and C. G. Waywell[1]

Major attention was given to tests of Simazine alone and with chlorate; to winter applications of pellets and solutions of Simazine and Urox, and to tests of herbicidal oils fortified with various chemicals. Work with CMU–chlorate (chlorea), unfortified oils, and repeat treatments was continued. In addition one-mile strips of weedy track were treated with previously recommended chemicals to demonstrate their effectiveness. A planned re-treatment of many of last-year's plots at Kanawha was abandoned when the area was inadvertently sprayed with Chlorea by the railroad crew.

Procedures were as previously reported. Sprays were applied with a power sprayer mounted on a push car and spraying a strip one rod wide. Dry chemicals were weighed and distributed carefully by hand. Plots were again two rods long with a check plot strip between each pair of treatments. Control was estimated by comparing each plot with the adjoining check plot. All treatments were replicated three to five times. Data shown in the tables are an average of the percentage vegetation control on the replicate treatments.

Weather was more normal than in 1957, and rainfall was moderate to very light for some weeks after the earlier treatments were applied. July rainfall was above normal, but the remainder of the season was dry. Plots were laid out on the Minneapolis & St. Louis Railway tracks between Denhart and Kanawha in north central Iowa, and on the Fort Dodge, Des Moines & Southern Railway lines south of Ames.

Tests with Substituted Urea Compounds and Simazine

Three series of tests contained substituted urea compounds or mixtures containing these compounds and Simazine. The first of these consisted of a winter application, made December 22, 1957, of Simazine and Urox, the latter a 3-(p-chlorophenyl)-1, 1–dimethylurea–trichloroacetate combination. The treated plots were not disturbed between December 22 and the date of scoring for vegetation control on September 19, 1958. The treatments and resultant data are shown in Table 1. Values for least significant

TABLE 1—WINTER APPLICATIONS OF SIMAZINE AND UROX AT AMES

Chemical	*Form*	*Rate Lb/A* [2]	*Vegetation Control* [1]				
			Rep. 1	*Rep. 2*	*Rep. 3*	*Avg.*	*Rank*
Simazine	Pellets	10	65	25	22	37	8
Simazine	Pellets	20	82	75	37	65	6
Simazine	Solution	10	77	70	45	64	7
Simazine	Solution	20	92	84	91	89	3
Simazine Plus 100 lb Chlorate	Solution	10	90	97	82	90	2
Simazine Plus 100 lb Chlorate	Solution	20	98	98	98	98	1
Urox	Pellets	20	77	55	75	69	5
Urox	Pellets	30	87	87	72	82	4

[1]Least significant difference; 5% = 21.5, 1% = 29.8.
[2]Active ingredient.

difference were obtained by an analysis of variance. Considering the rapid changes in ballast and vegetation characteristics of track of the type used here, on the FDDM&S south of Ames, these values are reasonably low. They indicate that differences between treatments of less than 20 percent were not fully established for the conditions of the

[1] Professor, formerly associate, and associate, respectively, Iowa Agricultural Experiment Station, Ames, Iowa.

experiment. Thus the control by 30 lb active ingredient of Urox pellets was 13 percent more than that by 20 lb, active ingredient a difference which was not statistically significant. The addition of 100 lb of chlorate to 10 lb of Simazine, however, increased the control by 26 percent, and the odds are thus close to 100 to 1 that a similar result would be obtained if the treatments were repeated under the same conditions. Similar odds apply to the conclusion that application of Simazine in solution was better than the use of pellets.

Considering that pellets were used, the results obtained with 30 lb active ingredient of Urox justify further consideration. One might estimate that the use of a spray or of 40 lb active ingredient of pellets would have given fully satisfactory control of this vegetation. The possibility of following moderately heavy winter treatments with summer sprays of oil also suggests itself.

Keeping in mind that different results might have been obtained if the ballast, vegetation or weather had been different, we can conclude: (1) That winter applications of these chemicals show promise and should be tried where their use would have economic or other advantages. From other and past experiments we would expect results with CMU [Telvar W or monuron-3 (p-chlorophenyl)–1, 1-dimenthylureal] similar to those obtained with Simzaine. (2) That solutions are better than pellets. We have had this indication in all comparisons of these two forms on track in Iowa. (3) That Simazine applications may be markedly improved by adding chlorate at the light rate of less than ⅔ lb per sq rod.

The largest single experiment run during the year was a test of CMU and Simazine with and without added chlorate in the fire retardant form of Chlorax (Chlorate–borate). Four of the heavier treatments in this experiment fell by chance on plots infested with essentially pure stands of perennial or swamp smartweed *(Polygonum coccineum)* which is not controlled by recommended chemical applications for general track use (Fig. 1). The result was one apparently poor replication and two very good ones for these treatments.

The four smartweed plots were considered as missing, and were handled by the missing plot technique. The data market by asterisks in Table 2 are the value cal-

TABLE 2—FACTORIAL COMBINATIONS OF CHLORATE, CMU, AND SIMAZINE—1958

Chemical, Lb Active/A			*Vegetation Control*			
Chlorate[1]	*CMU*	*Simazine*	*Rep. 1*	*Rep. 2*	*Rep. 3*	*Avg.*
0	0	5	30	45	60	45
0	0	10	37	75	77	63
0	5	0	32	25	12	23
0	10	0	55	88	80	74
0	5	5	92	81	78	84
100	0	0	10	12	22	15
100	0	5	79*	80	94	84
100	0	10	96	85	95	92
100	5	0	87	80	91*	86
100	10	0	84*	95	90	90
100	5	5	85*	93	95	91
200	0	0	10	25	45	27
200	0	5	92	87	98	92
200	0	10	96	96	90	94
200	5	0	67	92	95	85
200	10	0	82	96	94	91
200	5	5	91	82	95	89

[1]Applied in form of Chlorax (sodium chlorate 40%, sodium metaborate 57%).
*Data for plots heavily infested with perennial smartweed calculated by missing plot technique.

Fig. 1—Resistant weeds, perennial smartweed on the left and horsetail on the right, after five annual applications of 10 lb of CMU.

culated in this manner. An analysis of variance showed that there were highly significant differences among the treatments of the experiment, but we have not felt justified in calculating least significant differences from the corrected data. As an estimate, differences of 20 points are considered to be statistically significant.

The data of Table 2 show: (1) That, under the conditions of the experiment, CMU (Telvar W or monuron) and Simazine were equivalent, pound for pound of active ingredient. (2) That the addition of 100 lb of chlorate more than doubled the effectiveness of 5 lb of CMU or Simazine and gave a slightly better average control than 10 lb of these chemicals applied alone. (3) That the second 5 lb of CMU or Simazine or the second 100 lb of chlorate gave only small increases in percentage control. Results with CMU-chlorate in past seasons have generally shown definite advantages in increasing CMU from 5 lb actual to at least 8 lb, so that the controls obtained in this experiment can be considered to be better than average.

We have previously recommended that small areas of weeds, such as perennial smartweed, that are very difficult to control, be hand treated with heavy rates of chlorate or other chemicals rather than to use a general spray treatment strong enough to be effective against these resistant weeds.

Repeated Treatments

The year 1958 was the sixth year for the long-term, repeated treatment plots south of Ames. Plots in the "B" group, treated every other year, were not sprayed in 1958.

It is therefore possible to estimate the carry-over effect of the chemicals of these plots. Only the plots of treatment 7 which had received 20 lb of CMU in each of the years 1953, 1955, and 1957 gave full control (more than 90 percent) after one year without treatment. The 79 percent control for CMU-chlorate (10–80 lb per acre, respectively) applied in alternate years may be considered to be satisfactory. CMU alone at 10 lb gave only a 64 percent carry-over, and all other treatments were below 25 percent. Even when applied each year, only CMU, 20 lb, CMU-chlorate, 10–80 lb gave full control, and CMU, 10 lb gave satisfactory control at the end of the season.

In contrast, when the regular spray on May 12 was followed by 100 gal of herbicidal oil during the middle of August, all treatments except oil followed by oil gave essentially full control. The late oil spray was applied about three weeks later than normal this year, and this delay is assumed to have been responsible for the relatively poor showing of oil plus oil. Most of the weeds on these plots were annuals that had made so much growth by the time of the second spray that they were not fully controlled. These results point up the importance of timeliness in weed-control work.

The general results of this test suggest that there is no probability of permanent, one-shot control of on-track vegetation. On the other hand, relatively simple and inexpensive treatments can be effective if applied at the proper time and followed up consistently.

Table 3—Results with Repeated Treatments—1958

Chemicals and Rate/Acre[2]	*Vegetation Control*[1]		
	Every Year	*Every Year Plus Oil*	*Every Other Year*[3]
CMU-chlorate, 10–80 lb	95	99	79
TCA-chlorate, 40–80[4] lb	36	95	21
TCA, 40 lb	24	89	11
Oil (L-8764) 100 gal	39	76	25
TCA-chlorate, 40–80 lb	35	97	35
Chlorate, 80 lb	56	97	12
CMU, 20 lb	99	99	95
CMU, 10 lb	86	98	64

[1]Least significant difference: 5% = 12.4, 1% = 18.0.
[2]Active ingredient.
[3]Not treated in 1958.
[4]Plus 2 lb 2,4-D.

Tests with Herbicidal Oils

Three series of oil tests were run in 1958, two at Denhart in north central Iowa and one at Ames. A test of seven herbicidal oils, similar to the test run at Ames last year, was applied at Denhart on July 29 and rated on September 18. The late application was intended to prevent seeding of annuals and to give the maximum all-season control. The oils were medium to heavy aromatic oils, except Agronyl–R which is a very heavy oil. All oils gave significant general vegetation control, but only two oils, Cox–6 and Conoco–B, differed at the five percent level of significance. On the basis of these and past results we estimate that two sprays about June and August 15 would have given reasonably good weed control on this very foul track. One application was not enough. The data are shown in Table 4. All oils were applied at 100 gal an acre.

Table 4—A Test of Seven Herbicidal Oils in North Iowa—1958

Oil	Vegetation Control[1]			
	Rep. 1	Rep. 2	Rep. 3	Avg.
Cox-6	22	17	35	25
Cox-60	25	30	35	30
Cox-65	30	40	30	33
Conoco-A	42	37	10	30
Conoco-B	47	45	47	46
Agronyl-R	50	30	27	36
Stand.-L-8764	27	57	40	41

[1]Least significant difference: 5% = 18.6, 1% = 25.9.

The second test at Denhart was based on the heavy catalytic cycle oil, Standard of Indiana No. L–8764, and concerned the effect of various oil-soluble additives in increasing the toxicity of an oil of this type. Chemicals added were trichlorobenzoic acid (TBA), 3–(p–chlorophenyl)–1, 1–dimenthlurea (monuron or CMU), hexochloroacetone (HCA), and a mixed organic sulfide. Diesel oil was compared with the heavy catalytic oil in one test. The data in Table 5 show the oil, additive chemical, and rate of chemical in lb active ingredient per acre. Sprays were applied at 100 gal an acre on June 12, and ratings were made on September 18.

TBA at 24 lb and CMU at 10 lb in oil gave satisfactory vegetation control although we are not convinced that this is the most economical way to use these chemicals. HCA had little effect on broad-leaved plants, which tended to expand into the area left by the reduction of grasses by this spray. There appears to have been a synergistic action between L–8764 and HCA at the higher rates in the control of grasses, and a similar action with the sulfides.

Something of the effect of later spraying on end of season control by oils can be obtained by comparing L–8764 applied June 12, 17 percent in Table 5, with the 41 percent shown in Table 4 for a July 29 spray. The difference represents regrowth of perennials and infestation with late annual weeds after a spray with only moderate residual effects.

Table 5—Effects of Various Added Chemicals on Weed Control by a Heavy Catalytic and a Diesel Oil—1958

Oil	Chemical and Rate	Vegetation Control[1]	
		Grasses Only	All Veg.
L-8764	TBA, 24 lb	79	82
L-8764	TBA, 12 lb	60	64
L-8764	TBA, 6 lb	52	57
L-8764	CMU, 10 lb	81	80
L-8764	HCA, 6 lb	65	23
L-8764	HCA, 3 lb	48	25
L-8764	HCA, 1.5 lb	28	23
Diesel	HCA, 6 lb	36	25
Diesel	HCA, 3 lb	25	21
Diesel	HCA, 1.5 lb	24	21
L-8764	Sulfides	39	25
L-8764	Control	18	17
Diesel	Control	13	15

[1]Least significant difference: Grasses only, 5% = 24, 1% = 32; all veg., 5% = 18, 1% = 25.

In a third test of oils, the plots at Ames which were sprayed with oils last year were resprayed, so far as possible with the same oils. Cox–65 was substitute for Cox–77 and Conoco–B for the Lion Oil Co, LHO–6, which were not available this year. The oils were applied at the rate of 100 gal an acre on June 27, which is considered to be a desirable date for single oil sprays in this area.

Vegetation was light on this strip of track, consisting mainly of blue grass and annual weeds. The check plots looked bad, however, (Fig. 2) and the treated plots were good (Fig. 3). The data are shown in Table 6. All of the oils may be considered to have given a satisfactory vegetation control under the conditions of the experiment. A comparison of the data of Table 6 with those of Table 4 will illustrate the need of interpreting single experiments with caution, even after statistical analysis. Cox–65 was, on an average, poorer than Cox–6 at Ames but better at Denhart, while the reversal of the Conoco oils in the two experiments approached statistical significance.

TABLE 6—SECOND YEAR OIL SPRAYS AT AMES, IOWA—1958

Oil	*Vegetation Control*[1]			
	Rep. 1	*Rep. 2*	*Rep. 3*	*Avg.*
Cox-6	87	70	87	81
Cox-60	87	85	82	85
Cox-65	65	77	87	76
Conoco-A	80	92	90	87
Conoco-B	80	75	77	77
Agronyl-R	75	70	93	79
Stand.-L-8764	90	92	95	92
Stand.-L-8764 + CMU, 10	98	92	99	96

[1]Least significant difference: 5% = 11.2, 1% = 15.4.

Summary

Since this will be the last report to the AAR from Iowa, a few general conclusions on the trend of the work here should be in order.

Vegetation control on track can be divided into root kill to eradicate perennials and top kill to eliminate annuals or reduce interference of perennials. Root kill can be obtained by a herbicide that is translocated downward through the roots, or by one that penetrates the soil and acts directly upon the roots. Translocation of herbicides involves the movement of poisons through delicate living tissues, and is difficult at the best. Translocated applications are not essential on track, as they may be in a cultivated field, and we, personally, would not ordinarily use 2,4–D, for example, in roadbed work. In addition to the damage hazards, the Iowa work has shown no clear-cut demonstration of the value of 2,4–D in track work. Brush-mix may have a place in brush control on the right-of-way, but not, in our opinion for general use on track.

Where translocated chemicals, such as brush-mix, are used they should not be mixed with top-killing chemicals which will completely prevent translocation by killing the tissues concerned. Also, over-doses of translocated chemicals have the same effect. One-half lb of 2,4–D per acre can do a better job of killing Canada thistle than 2 lb, and 8 lb simply burns off the tops, leaving the roots to sprout promptly and vigorously.

When the fire hazard is controlled, as with Chlorax (sodium chlorate–metaborate mixture), sodium chlorate is one of the good root killers. It washes out of the top soil or ballast too rapidly under some conditions and decomposes rapidly in warm soil.

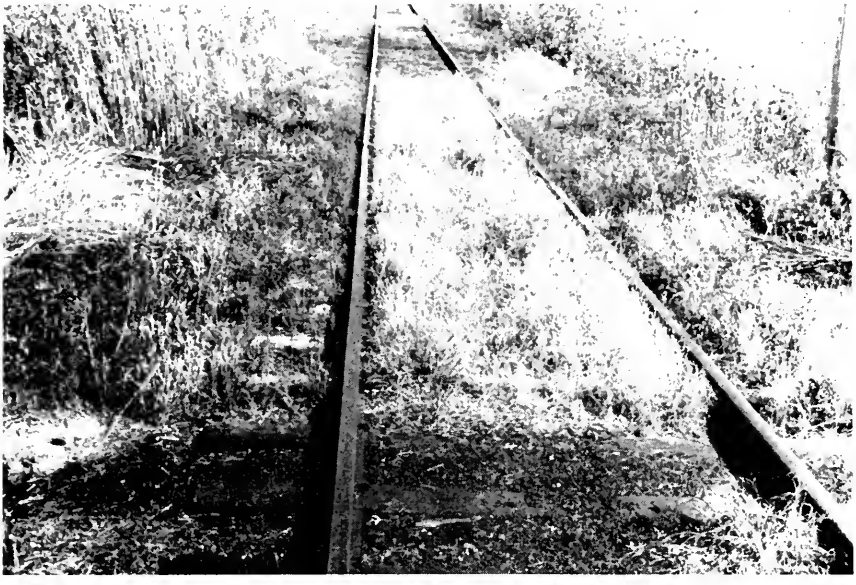


Fig. 2—Check plot in the repeat oil sprays showing annual weeds on track and perennials, mostly blue grass, on the shoulder.

Fig. 3—Control of moderately heavy vegetation (Fig. 2) by two years of spraying with 100 gal of a heavy catalytic cycle oil.

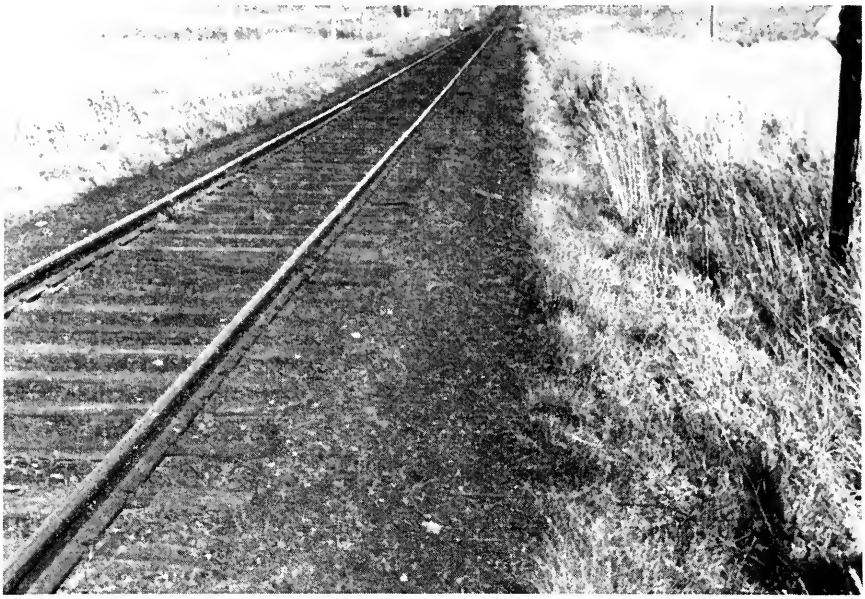


Fig. 4—Good weed control on heavy cinder ballast with a heavy catalytic oil.

Combinations of chlorate with substituted urea compounds have been our most effective soil-acting weed treatments in Iowa and are recommended for foul track with mixed weeds and grass.

Of the top killers or chemical mowers, the better herbicidal oils are, in our opinion, the best thing available (Fig. 4). They have no livestock hazards and their effectiveness is not destroyed by rain after application. Insofar as we have gone in determining the most active oil fraction, it appears to be among the polycyclic aromatics. Paraffine oils of moderately high boiling points also have a slow, chronic poisoning. We have found L–8764, with usually less than 40 percent aromatics, to be as effective as special weed-killer oils with 70 percent aromatics and, generally, with lower boiling points. For the present it does not seem feasible to buy herbicidal oils on specifications alone. There should be, in addition, evidence of their effectiveness as herbicides.

Finally, and perhaps more difficult to put into practice under present economic conditions, weed control requires persistant, continuing action. One year missed for budget reasons will allow for reinvasion of the track by perennials and the production of a new crop of seeds of annuals that will make trouble for years. Equally troublesome at times, the proper period for a particular spray may last no more than two or three weeks. The railroad that wishes to maintain a single spray train in operation for a maximum period cannot expect maximum results in vegetation control.

For the future—we hope that better, and especially cheaper phenylurea type of chemicals will become available, and that oils may be improved, either by refinery processes or by cheap additives.

Part 2—Railroad Weed Control, North Carolina State College

By Glenn C. Klingman and Merrill Wilcox[1]

A research program aimed toward roadbed weed control was started in North Carolina in the spring of 1957. The program has been conducted in cooperation with the Research Center of the Association of American Railroads, the Durham & Southern Railway and the Norfolk Southern Railway. The results at the end of the first growing season were reported as Part 2 of the report on Chemical Control of Vegetation, Committee on Roadway and Ballast, AREA Proceedings, Vol. 59, pages 843–850, 1958.

In the spring of 1957, when the experiment was started, the D&S roadbed between Holly Springs and Apex was lightly but rather uniformly infested with Bermuda grass *(Cynodon dactylon)*. In addition, it had a rather heavy infestation of woody plants, including cow-itch vine *(Campsis radicans)*, poison oak *(Rhus Toxicodendron)*, and blackberry *(Rubus spp.)* The roadbed is composed of coarse crushed granite. Cinders have not been used for many years.

The Norfolk Southern roadbed experimental area, located in the suburbs of Charlotte, N. C., was heavily infested with Bermuda grass. The roadbed is underlain by cinders, and considerable coarse sand bas been added in the last few years.

A spray boom covering 16½ ft was mounted on a small push car drawn by a motor car. This width covers 1 acre with each ½ mile of track, or 2 acres per mile. Each plot was 4 rails long and each treatment was replicated 3 times.

The chemicals were applied on the dates, at the rates and in the amount of spray mixture shown in Tables 1 and 2. In most cases, this was the second year of treatment on the same plots with the same herbicides. The amount of spray mixture was normally 33 gal per acre, or 66 gal per mile, unless there was a specific need for larger amounts.

Results

Most treatments resulted in considerably better weed control at the end of the second year than appeared at the end of the first year. It is anticipated that the degree of weed control will continue to improve through the third year.

The rate of chemical treatment was reduced with a few treatments this year, reducing costs. It is anticipated that a number of chemical rates of treatment can be reduced in the third year.

At the end of the 1958 season the principal woody species remaining on the Holly Springs experimental area was cow-itch vine. Failure to control this species is reflected in occasional low broad-leaved weed control ratings, Table 2.

Each treatment will be discussed briefly. In some cases it will be desirable to discuss several treatments as a group. Reference to various treatments will be given as to location. The letters "Ch" will be used for Charlotte and "H. S." for Holly Springs. Treatment is abbreviated as Tr., and refers to the treatment number given in the left column of Tables 1 and 2.

Dalapon applied twice at the rate of 10 lb per acre (Tr. 1) gave good grass control and poor broad-leaved control at both locations. The dalapon was giving obvious injury to some of the broad-leaved perennials. It is possible that continued repeated treatments may give control of some species in this group.

Dalapon (40 lb per acre) and 2,4–D (8 lb per acre) applied once (Tr. 2) gave

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TABLE 1. CHARLOTTE, NORTH CAROLINA - NORFOLK SOUTHERN RAILWAY

Treat No.	Chemical[1], Rate Per Acre (Lb or Gal), and Date of Application: July 17-18, 1957	Aug. 7-8, 1957	June 4-5, 1958	July 9-10, 1958	Gal Spray	Weed Ratings[2], Oct. 16, 1958: Grass	Broad-Leaved	Avg. Grass and Broad-Leaved
1	Dalapoo 10	Dalapon 10	Dalapon 10	Dalapoo 10	33	7.0	2.7	4.8
2	Dalapon 40 2,4-D 8	None	Dalapon 40 2,4-D 8	None	33	5.0	5.0	5.0
3	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	33	7.3	6.7	7.0
4	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2	Dalapoo 10 2,4-D 2	Dalapon 10 2,4-D 2	33	6.7	7 0	8.8
5	Dalapon 10 2,4-D 2 Diuron 10	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2 Diuron 10	Dalapon 10 2,4-D 2	33	8.7	9.3	9.0
6	Dalapon 10 2,4-D 2 Simazine 10	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2 Simazine 10	Dalapon, 10 2,4-D 2	33	8.7	9 0	8.8
7	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	33	5.0	4.0	4.5
8	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	33	5.7	5.3	5.5
9	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	33	7.0	6.3	6.6
10	Dalapon 10 Diuron 10	Dalapon 10	Dalapon 10 Diuron 10	Dalapon 10	33	9.0	9.3	9 2
11	ATA 5 PBA(354) 4	ATA 5 PBA(354) 4	ATA 5 PCP 6 lb/A	ATA 5 PCP 6 lb/A	33	6.0	7.3	6.6
12	ATA 5 + W.A. PBA(354) 4 Simazine 10	ATA 5 + W.A. PBA(354) 4	ATA 5 Simazine 20	None	33	6.7	7.0	6.6
13	ATA 5 + W.A. 2,4-D 2	ATA 5 + W.A. 2,4-D 2	TCI 20 ATA 5	TCI 20 ATA 5	33	2.0	2.7	2.4
14	ATA 5 + W.A. Dalapon 10	ATA 5 + W.A. Dalapon 10	ATA 5 Dalapon 10	ATA 5 Dalapon 10	33	6.3	7.3	6.8
15	Conoco Oil 100	None	Conoco Oil 100	None	100	3.3	4.0	3.6
16	Agronyl-R 100	None	Agronyl-R 100	None	100	3.0	4.3	3.6
17	Agronyl-R 100 Simazine 10	None	Conoco Oil 100 Simazine 10	None	100	7.7	7.7	7.7
18	Agronyl-R 100 Diuron 10	None	Conoco Oil 100 Diuron 10	None	100	8.3	8.0	8.2
19	Agronyl-R 48 HCA-2 Gal	Agronyl-R 48 HCA-2 Gal	Conoco Oil 47 HCA-3 Gal	Conoco Oil 47 HCA-3 Gal	30	7.0	6.3	6.6
20	Agronyl-R 45 PBA(103-A) 10	Agronyl-R 45 PBA(103-A) 10	Conoco Oil 45 PBA-94A 10	Conoco Oil 45 PBA-94A 10	30	7.0	8 0	7.5
21	Agronyl-R 43 Mon-TCA 21	Agronyl-R 43 Mon-TCA 21	Conoco Oil 43 Mon-TCA 21	Conoco Oil 43 Mon-TCA 21	50	8.3	8.3	8.3
22	Fen-TCA 21	Fen-TCA 21	Fen-TCA 21	Fen-TCA 21	33	6.0	7.3	6.6
23	Chlorax Liq. 100 Diuron 10	None	Chlorax Liq. 100 Diuron 10	None	100	8.7	9.3	9.0
24	Chlorax Liq 50 Diuron 5	Chlorax Liq. 50 Diuron 5	Chlorax Liq. 50 Diuron 5	Chlorax Liq. 50 Diuroo 5	33	8.3	9.0	8.7
25	Monsanto 10847 20	Monsanto 10847 20	Herb. NP-ATA 165 Gal	Herb. NP-ATA 165 Gal	33	8.0	8.0	8.0
26	Monsanto 13842 20	Monsanto 13842 20	FB 2 G-30027 10	FB 2 G-30027 10	33	7.0	7.3	7.2
27	Erbon 120	None	Erbon 120	None	33	8.3	9.0	8.6
28	Diuron 40	None	Diuron 40	None	33	9.0	9.7	9.4
29	Simazine 40	None	Simazine 40	None	33	9.3	9.0	9.2
30	Ureabor 872	None	Ureabor 872	None	Gran	9.0	9.7	9.3
31	Chlorea 872	None	Chlorea 872	Nooe	Gran.	9.3	9.3	9.3
32	Atlacide-2,4-D 872	None	Atlacide-2,4-D 872	None	Gran.	8.0	8.3	8.2
33	Check	-	G-30027 20	None		5.7	5.7	5.7
34	Check	-	RHB(D) 45 Gal/A	RHB(D) 45 Gal/A	180(1958)	4 3	4 0	4.2
35	Check	-	Check	-		0 0	0.0	0.0

[1] See Table 3 "Chemicals Used"

[2] Weed Ratings - 10 - Perfect Control 0 - No Control

Least Significant Difference (.05)	1 84	1 54
Least Significant Difference (.01)	2 44	2.05
Coefficient of Variability	17%	14%

TABLE 2. HOLLY SPRINGS, NORTH CAROLINA - DURHAM AND SOUTHERN RAILWAY

Treat No.	Chemical[1], Rate Per Acre (Lb or Gal), and Date of Application: May 10, 1957	June 6, 1957	May 19, 1958	June 23, 1958	Gal Spray	Weed Ratings[2], Oct. 17, 1958: Grass	Broad-Leaved	Avg. Grass and Broad-Leaved
1	Dalapon 10	Dalapon 10	Dalapon 10	Dalapon 10	33	8.0	4.7	6.4
2	Dalapon 40 2,4-D 8		Dalapon 40 2,4-D 8		33	7.3	4.3	5.8
3	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	Dalapon 20 2,4-D 4	33	9.0	7.0	8.0
4	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2	33	6.3	6.7	6.5
5	Dalapon 10 2,4-D 2 Diuron 10	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2 Diuron 10	Dalapon 10 2,4-D 2	33	9.0	8.0	8.5
6	Dalapon 10 2,4-D 2 Simazine 10	Dalapon 10 2,4-D 2	Dalapon 10 2,4-D 2 Simazine 10	Dalapon 10 2,4-D 2	33	7.7	6.7	7.2
7	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	Dalapon 10 2,4,5-T 2	33	6.3	5.0	5.7
8	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	Dalapon 10 2(2,4,5-T)P 2	33	6.3	5.3	5.8
9	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	Dalapon 10 PBA(354) 4	33	5.7	7.0	6.4
10	Dalapon 10 Diuron 10	Dalapon 10	Dalapon 10 Diuron 10	Dalapon 10	33	9.0	7.0	8.0
11	ATA 5 PBA(351) 4	ATA 5 PBA(354) 4	None	ATA 5 PCP 6	33	3.3	5.7	4.5
12	ATA 5 2,4-D 2	ATA 5 2,4-D 2	ATA 5 Diuron 20,TCA 20	None	33	9.3	8.3	8.8
13	None	Agronyl-R(100)	Agronyl-R(100)	None	100	5.3	5.0	5.2
14	None	Conoco Oil (100)	Conoco Oil (100)	None	100	5.7	4.0	4.8
15	Agronyl-R 48 HCA 2	Agronyl-R 48 HCA 2	Conoco Oil 47 HCA 3	Conoco Oil 47 HCA 3	50	7.0	6.0	6.5
16	Agronyl-R 48 HCA 2,Simazine 10	Agronyl-R 48 HCA 2	Conoco Oil 47 HCA 3,Simazine 10	Conoco Oil 47 HCA 3	50	9.3	4.7	7.0
17	Agronyl-R 45 PBA(103-A) 10 Simazine 10	Agronyl-R 45 PBA(103-A) 10	Conoco Oil 45 PBA(103-A) 10	Conoco Oil 45 PBA(94A) 10	50	9.3	8.7	9.0
18	Agronyl-R 43 Mon-TCA 21	Agronyl-R 43 Mon-TCA 21	Conoco Oil 46 1/2 Mon-TCA 10 1/2	Conoco Oil 46 1/2 Mon-TCA 10 1/2	50	9.7	8.7	9.2
19	Fen-TCA 21	Fen-TCA 21	Fen-TCA 10 1/2	Fen-TCA 10 1/2	33	10.0	9.7	9.9
20	Chlorax Liq. 50 100 Gal Diuron 10	None	Chlorax Liq. 100 Gal Diuron 10	None	100	9.3	6.3	7.8
21	Chlorax Liq. 50 Diuron 5	Chlorax Liq. 50 Diuron 5	Chlorax Liq. 50 Diuron 5	Chlorax Liq. 50 Diuron 5	50	9.3	7.3	8.3
22	Monsanto 9303 40	None	Herb. NP-ATA 165 Gal	Herb. NP-ATA 165 Gal	33	8.7	8.3	8.5
23	Monsanto 9303 20	Monsanto 9303 20	FB2 2 G-30027 10	FB2 2 G-30027 10	33	7.7	7.7	7.7
24	Erbon (Baron) 120	None	Erbon (Baron) 60	None	33	8.7	8.3	8.5
25	Diuron 40	None	Diuron 40	None	33	10.0	8.3	9.2
26	Simazine 40	None	Simazine 40	None	33	8.0	7.3	7.6
27	Ureabor 872	None	Ureabor 436	None	Gran.	9.7	9.3	9.5
28	Chlorea 872	None	Chlorea 436	None	Gran.	9.7	8.7	9.2
29	Atlacide-2,4-D 872	None	Atlacide-2,4-D 436	None	Gran.	9.0	7.0	8.0
30	Check		Check			0.0	0.0	0.0

[1] See Table 3 "Chemicals Used"

[2] Weed Ratings - 10 - Perfect Control, 0 - No Control

Least Significant Difference (.05)	1.64	1.75
Least Significant Difference (.01)	2.17	2.33
Coefficient of Variability	13%	16%

TABLE 3. CHEMICALS USED

Chemical	Active Ingredient	Trade Name	Provided By
Dalapon	71%	Radapon	Dow Chemical Company
TCA	90%	TCA Grasskiller	Amchem Products, Inc.
TCI-Trichloro isobutyric Acid	2 Lb/Gal	ACP M540	Amchem Products, Inc.
Emuls. PCP	1 Lb/Gal	ACP M604	Amchem Products, Inc.
HCA	20%	HCA Weed Killer Concentrate	General Chemical Division Allied Chemical & Dye Corp.
Ethylene dipyridilium dibromide	4 Lb/Gal	FB2	Chipman Chemical Company
Amino Triazole (ATA)	50%	Weedazol	Amchem Products, Inc.
2,4-D Amine (1957 only)	4 Lb/Gal	2,4-Dow Weed Killer	Dow Chemical Company
2,4-D Amine (1958)	4 Lb/Gal	2,4-D Weed Killer	Monsanto Chemical Company
2,4,5-T Amine (1957 only)	4 Lb/Gal	Dow 2,4,5-T Amine Weed Killer	Dow Chemical Company
2,4,5-T Amine (1958)	4 Lb/Gal	Veon 245	Dow Chemical Company
2(2,4,5-T)P	4 Lb/Gal	Kuron	Dow Chemical Company
Poly Benzoic Acid (PBA)	2 Lb/Gal	ACP Benzac 103-A	Amchem Products, Inc.
Poly Benzoic Acid (PBA)	2 Lb/Gal	ACP M94A	Amchem Products, Inc.
Poly Benzoic Acid (PBA)	4 Lb/Gal	ACP-M-354	Amchem Products, Inc.
Erbon	4 Lb/Gal	Baron	Dow Chemical Company
Diuron (Karmex)	80%	Karmex DW	E. I. duPont de Nemours & Co.
Simazine	50%	Simazine	Geigy Agricultural Chemicals
G-30027	50%	G-30027	Geigy Agricultural Chemicals
Monuron-TCA	3 Lb/Gal	Compound 2996	General Chemical Division Allied Chemical & Dye Corp.
Fenuron-TCA	3 Lb/Gal	Compound 2603	General Chemical Division Allied Chemical & Dye Corp.
Sodium Chlorate Sodium Metaborate	2 Lb/Gal 1.67 Lb/Gal	Chlorax Liquid	Chipman Chemical Company
Sodium Chlorate 2,4-D	58% .06%	Atlacide 2,4-D	Chipman Chemical Company
Sodium Chlorate Sodium Metaborate Monuron (Telvar W-80%)	40% 57% 1%	Chlorea	Chipman Chemical Company
Sodium TCA Sodium Chlorate Calcium Chloride	14.24% 28.49% 17.09%	RHB (Spec. D) Weed Killer	R. H. Bogle Company
Borate Compounds Monuron (Telvar W)	94% 4%	Ureabor	U.S. Borax & Chemical Corp.
Weed Killing Oil	100%	Agronyl-R	Socony Mobil Oil Company, Inc.
Weed Killing Oil	100%	Conoco Weed Spray Oil	Continental Oil Company
Oil Cresols Xylenols Phenols	21.4% 1.8% 1.2% 0.5%	Herbicidol NP-ATA	Reade Manufacturing Company
Sodium TCA 2,4-D Amizol (Amino Triazole) Surfactants	7.0% 1.1% 0.7% 12.0%		
Coded	Coded	Monsanto 9303	Monsanto Chemical Company
Coded	Coded	Monsanto 10847	Monsanto Chemical Company
Coded	Coded	Monsanto 13842	Monsanto Chemical Company

only fair broad-leaved control at Charlotte and Holly Springs, with good control of grass at Holly Springs and fair control at Charlotte. The high rate of chemical application quickly kills the tops, but does not favor translocation of the herbicide to below ground parts.

Dalapon (20 lb per acre) and 2,4–D (4 lb per acre) applied twice (Tr. 3) gave good grass and broad-leaved control at both locations. One-half of this rate (Tr. 4) gave approximately the same control at Charlotte and about the same broad-leaved control at Holly Springs. The data indicate better grass control at Holly Springs at the higher rate of dalapon and 2,4–D.

The addition of diuron (10 lb per acre) (Tr. 5), or Simazine (10 lb per acre) (Tr. 6) to dalapon and 2,4–D (Tr. 4) showed an increase in weed control at both locations. This trend was not evident the first year. The three herbicides mixed together (Tr. 5 and 6) gave excellent grass and broad-leaved control at both locations.

Dalapon (10 lb per acre) and diuron (10 lb per acre) (Tr. 10) gave excellent grass and broad-leaved control at both locations (Figs. 1 and 2). Additional research is needed to establish the value of 2,4–D (Tr. 5) to the above herbicide mixtures.

Dalapon (10 lb per acre) mixed with 2,4,5–T (Tr. 7), with 2 (2,4,5–T)P (Tr. 8), or with PBA (Tr. 9) gave no increase in weed control beyond that obtained with equivalent rates of 2,4–D (Tr. 4).

Treatment 11 was shifted in 1958 to a combination of amino triazole (ATA) (5 lb per acre) and pentachlorophenol (PCP) (6 lb per acre). Two applications at Charlotte gave fair to good grass and broad-leaved control. One application at Holly Springs gave poor grass control and fair broad-leaved control. It should be emphasized that this was the first year of treatment with this combination, compared to two years of treatment with most other chemicals.

Treatment 12 at Charlotte was changed in 1958 by omitting PBA and by increasing the rate of Simazine to 20 lb per acre. Amino triazole (5 lb per acre) was retained at the same rate. Fair to good grass and broad-leaved weed control was the result.

Treatment 13 at Charlotte was changed to TCI (20 lb per acre) and amino triazole (5 lb per acre) in 1958. This combination gave poor control.

Amino triazole (5 lb per acre) and dalapon (10 lb per acre) applied at Charlotte (Tr. 14) gave fair to good grass and broad-leaved control.

Amino triazole (5 lb per acre), diuron (20 lb per acre), and TCA (20 lb per acre) at Holly Springs (Tr. 12) gave good to excellent grass and broad-leaved control.

Weed killing oils alone (Ch. Tr. 15, 16; H. S. Tr. 13, 14) applied as wetting sprays gave quick top-kill of all vegetation. Perennial species developed regrowth so that by the end of the growing season the plots were rated as giving poor to fair grass and broad-leaved control.

Weed oil plus hexachloroacetone (Ch. Tr. 19, H. S. Tr. 15) gave good grass and good broad-leaved weed control at both locations. The addition of Simazine to the above chemicals (H. S. Tr. 16) gave excellent grass control.

The addition of diuron (10 lb per acre) or Simazine (10 lb per acre) to the oil (Ch. Tr. 17, 18) increased the control of both grasses and broad-leaved weeds to good. (Fig. 3). The addition of PBA (10 lb per acre) increased the control to excellent at Holly Springs (Tr. 17) and to good at Charlotte (Tr. 20). The addition of monuron–TCA to the oil resulted in excellent weed control at Holly Springs (Tr. 18). Control was good enough in 1957 that the monuron–TCA rate of application was reduced by one-half in 1958. The rate was continued at Charlotte (Tr. 21) resulting in good grass and broad-leaved control.

Fig. 1—Dalapon (10 lb/A) applied twice in 1957. Diuron (10 lb/A applied with first treatment of dalapon (Ch. Plot 14, Tr. 10). Picture taken Aug. 13, 1957.

Fig. 2—Dalapon (10 lb/A) applied twice in 1957 and twice in 1958. Diuron (10 lb/A) applied with first treatment of dalapon each season (Ch. Plot 14, Tr. 10). Same test plot as Fig. 1. Picture taken Oct. 16, 1958.

Fig. 3—Area not treated (check plot), showing heavy growth of Bermuda grass, annual weeds and woody plants along the edge. Plot 3 beyond the telephone pole was Conoco Oil (100 gal) and diuron (10 lb/A) (Ch. Tr. 18).

Fenuron–TCA (21 lb per acre) gave excellent weed control at Holly Springs (Tr. 19). Control was sufficiently good in 1957 that the applied rate was reduced by one-half in 1958. Oak trees growing 75 ft from the edge of the track were killed. At Charlotte (Tr. 22) weed control was fair to good. Several of the plots were in locations having a porous and open track. In these areas weed control was less effective than where the track was on a relatively heavy soil base.

Chlorax liquid and diuron (Ch. Tr. 23, 24; H. S. Tr. 20, 21) gave good to excellent grass and broad-leaved weed control at both locations. It would appear that there is little or no difference between split application of this herbicide spray mixture as compared to a single seasonal application.

Herbicidol NP ATA (H. S. Tr. 22; Ch. Tr. 25) gave good grass and broad-leaved weed control at both locations. This was the first year of application of this mixture. The control produced after only one season's treatment was very good compared to that obtained with many of the herbicides.

F. B. 2 and G–30027 (H. S. Tr. 23; Ch. Tr. 26) gave good grass and broad-leaved weed control at both locations. Therefore, control is considered very good for the end of one season's application.

Fig. 4—Simazine (40 lb/A) applied in 1957 and 1958. In 1957 this treatment received an average rating of 4.6, whereas in 1958 the average increased to 8.4 (Ch. Tr. 29; H. S. Tr. 26).

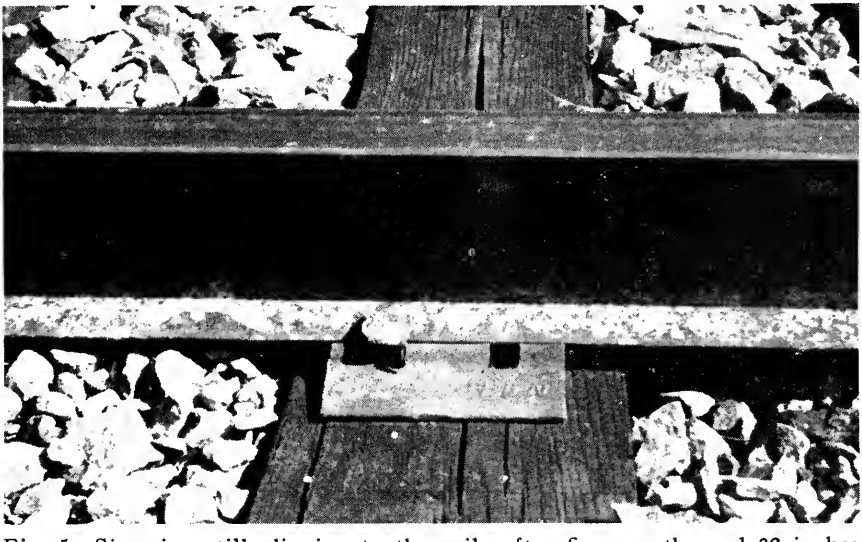

Fig. 5—Simazine still clinging to the rails after five months and 32 inches of rain. The upper surface of the crushed rock had a similar residue.

Fig. 6—Ureabor (872 lb/A in 1957; 436 lb/A in 1958) gave excellent grass and broad-leaved control. (H. S. Tr. 27; Ch. Tr. 30). The stems showing in the ballast are dead. At Charlotte the rate was not reduced in 1958.

G–30027 (Ch. Tr. 33) gave fair grass and broad-leaved weed control at Charlotte. The woody plants appeared very yellow in the fall of 1958. Plant survival in the spring of 1959 will be of considerable interest. Only one season's observations have been made.

Erbon (Ch. Tr. 27; H. S. Tr. 24) has given good to excellent grass and broad-leaved weed control at both locations. It gave good enough weed control at Holly Springs in 1957 that the rate of application was reduced to one-half in 1958.

Diuron (40 lb per acre) and Simazine (40 lb per acre), as individual treatments, gave good to excellent grass and broad-leaved weed control at both locations (Ch. Tr. 28, 29; H. S. Tr. 25, 26) (Fig. 4). The excellence of control at the end of the second season is of considerable interest, since neither herbicide was rated very highly at the end of the first season. The solubility of these materials are very low (Fig. 5). It is assumed that the rates may be reduced in years hence.

RHB (Special D) Weed Killer (Ch. Tr. 34) gave fair to poor weed control at Charlotte. It should be pointed out that this was the first year that this herbicide was applied on these plots. The rating given is comparable to the rating given many of the treatments at the end of the first season in 1957.

Ureabor, Chlorea, and Atlacide–2,4–D applied individually as granular treatments have all given good to excellent control (Fig. 6) (Ch. Tr. 30, 31, 32; H. S. Tr. 27, 28, 29). At Holly Springs the excellence of control obtained in 1957 made it possible to reduce the rate of chemical application by one-half.

Part 3—Chemical Control of Vegetation—1958 AAR Report

The 1958 season completed eight years of research into the problem of vegetation control on railroad rights-of-way under Assignment 11 of AREA Committee 1—Roadway and Ballast. Each year the AAR staff has made field observations evaluating the results of system-wide treatments as well as cooperative tests conducted between railroads and chemical companies throughout the United States and Canada. The results obtained from these treatments have been summarized and presented as information in the AREA Proceedings, Vols. 53 through 59.

Numerous chemicals and chemical combinations have been tested during the past eight years. Much progress has been made but as yet there is no chemical available that will solve all vegetation control problems found on railroads throughout the United States and Canada. At the present there are more than 50 materials available for the purpose of controlling weeds and brush on railroads. Each of these materials when applied at the recommended rates has been used successfully, depending upon the type of vegetation present, climatic conditions, length of growing season, type of soil and type of control desired.

As mentioned in previous reports, the AAR has divided the United States and Canada into seven regions for the purpose of evaluating more effectively the results of chemical treatments for weed and brush control (Fig. 1). A particular region has similar

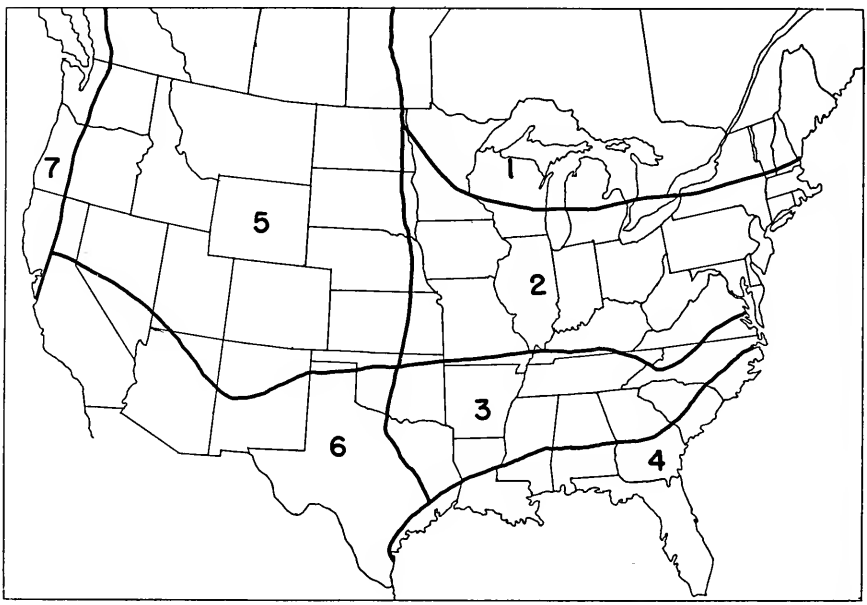

Fig. 1.

soil types, climatic conditions, types of vegetation and length of growing season, but some variations do occur within regions.

The AAR staff inspected system-wide treatments on 13 railroads for weed control and on 3 railroads for brush control in 6 of the 7 regions during the past season. The results of these observations are briefly discussed in this report. In addition, a number of large weed control test sections were followed on 14 railroads in 6 regions, some of which were initiated in 1956. Brush control tests using dry granular and pelletized materials were evaluated on three railroads in three regions. Specific results of these tests are summarized in Tables 1A through 7. These data are presented as information and are not intended to express approval or condemnation of any particular chemical treatment. It should be noted that the materials included in this report do not embrace all chemical treatments used in any specific region, but merely those inspected by the AAR staff.

Observations this year further substantiate the theory that a long-term system-wide weed control program is superior to one on a year-to-year basis. Although the initial expense involved in such a program may be high, a reduction in cost may be realized over an extended period.

Single applications of translocated and contact materials continued to provide fairly good seasonal control in regions 1 and 2, but reinfestation occurred during late summer where the rainfall was above normal. Repeated treatments were necessary in high rainfall areas with long growing seasons, regions 3 and 4. Split applications of these types of materials continued to be more effective than the single application at equivalent rates.

Soil sterilants or residual type materials maintained good seasonal control in all regions when used at the recommended rate. It is often possible to reduce the rate of application of these materials during a second season or it may be possible to omit the treatment during the second year in low rainfall areas.

Materials Used

Chemical combinations continue to be widely used for controlling weeds on main and branch lines in all regions. These combinations include chlorate–borate materials, chlorate–borate–substituted urea compounds, methoxone–chlorate–borate–substituted urea mixtures, chlorate– chloride, methoxone–chlorax, TCA–chlorate and dalapon–phenoxy compounds. One application of these materials will usually provide good seasonal control when used at the recommended rates in regions 1, 2, 5 and 6. Two applications are required in higher rainfall areas, regions 3 and 4, where the long growing season is conducive to vigorous plant growth. Mixtures containing soil-sterilant type materials were more effective in preventing regrowth during the late summer.

Soil-sterilant type materials were used primarily in yard areas, around bridges, communication poles, signal stands, buildings and at road crossings. Among those most widely used for these purposes were sodium arsenite, Baron, Borate slurry, Concentrated Borascu, Chlorea, Nalco H–174, Reade's M/W, Ureabor and Urox. In some regions these materials have been applied on the same area during successive years with excellent results. Nalco H–174 was applied on a main line in region 4 in strips of 18 and 24 in for controlling vegetation along the ballast toe line (Fig. 2). The results of these treatments were very good.

Herbicidal oils were used primarily in the Midwest and Southeast during the 1958 season. One application of oil provided fairly good control in the Midwest. Two and three applications were required in the Southeast to maintain seasonal control. Soil-

Fig. 2—Ballast toe line treatment with Nalco H–174 in Region 4. Treatment applied at 480 lb per acre April 23, 1958 on 18 in strips each side of track. Picture taken September 23, 1958.

sterilant materials such as monuron have been added to oils with much success in the Midwestern area. The oil provided the initial top kill and the monuron provided residual effects.

Atlas D–11 was used in the Midwest as a contact killer and its results were favorable.

Cost

The cost per mile for controlling vegetation with chemicals may vary considerably between railroads within a particular region. The cost per mile is determined by the type of material used, rate applied per acre and the width treated. Table 8 contains a list of materials used during 1958, showing the price range f.o.b. plant. The cost of any specific material is normally within this range but it is subject to adjustment by commercial applicators.

Special Problems

One railroad in region 3 used a spot treatment of hexachloroacetone in combination with oil for the control of Johnson grass during August 1957 (Fig. 3). A second application of HCA was made during August 1958 in a weed and brush spray mixture. This area was inspected during May and September 1958 to determine the effectiveness of HCA in controlling Johnson grass. Results indicated that approximately 80 to 85 percent of the Johnson grass had been eliminated.

Gamet D, a mixture of amino triazole and 2,4–D, was used on one railroad in region 3 for the control of trumpet vine during 1957. The application was made during June 1957. This area was inspected during May 1958 to determine the effectiveness of the material being translocated throughout the plant system and to estimate the percentage of regrowth. Results during 1957 indicated a very good top kill with minor resprouting. The May inspection revealed that the chemical had been translocated 3 to

Fig. 3—Johnson grass control with Hexachloroacetone in Cox Hykil in Region 3. Spot treatment applied mid-August 1957. Picture taken September 27, 1958. Note: this area is the same location as shown in Fig. 5, AREA Proceedings, Vol. 59, page 854.

12 in beneath the surface of the soil and ballast. It was estimated that approximately 65 to 70 percent of the trumpet vine was resprouting.

Trysben 200 looks promising in tests on one railroad in region 2 for controlling bouncing bet and field bindweed (Fig. 4). This material appears to be more effective on bindweed than on bouncing bet, but the results justify further evaluations of this product on bouncing bet.

Tests

Several tests were followed in six of the seven regions during 1958 (Tables 1A through 7). Some of these were initiated in 1956 for controlling vegetation on branch lines while others were established as long-term tests using granular materials in yard areas and on branch lines.

One railroad in region 1 established a long-term test during 1957 in yard areas using dry materials (Table 1A). Five materials were used on adjacent tracks at each of two locations covering areas from 1775 ft to 7609 ft in length and 14 ft wide. Re-treatment was made in 1958 on four of these tests in each location. One test at each location was not re-treated during 1958. Results were good in all areas. Some regrowth occurred in the area not re-treated in 1958. It is possible that the rates of these materials can be reduced next year.

A test in region 1 using MCP–chlorax–Simazine in a yard covering approximately 14 acres shows promise for controlling vegetation in this area. Results justify further evaluations of this combination. Other materials used in test sections in region 1 provided varying degrees of control. (Refer to Tables 1A and 1B for results).

Tests using dry granular materials were applied on a branch line in region 2 covering areas of 0.6 mi to 1.8 mi in length and 16 ft wide. Three materials were used, the results of which are shown in Table 2A (Fig. 5). These materials provided good results on all vegetation except deep-rooted species. Another railroad in this region tested a number of materials in yard areas (Table 2A). Telvar W, baron and Simazine

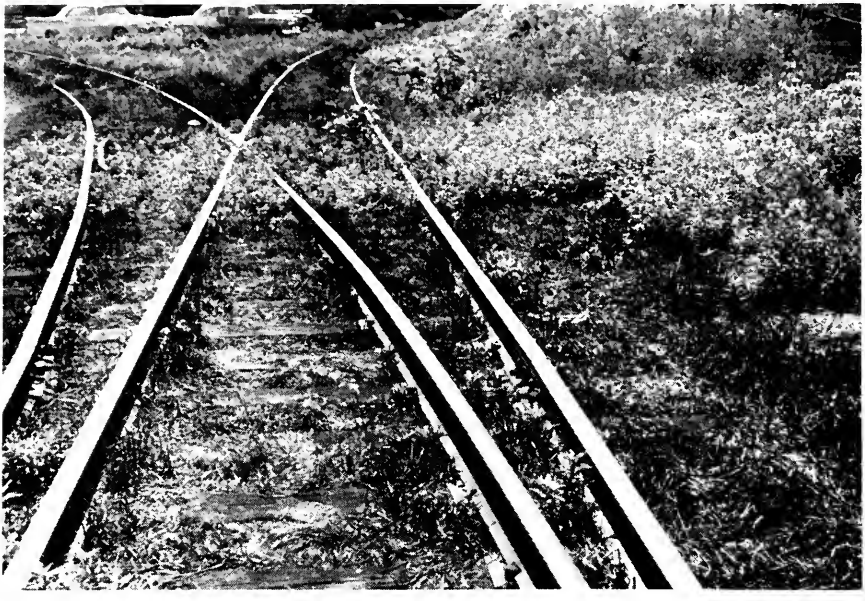

Fig. 4—Bouncing bet control using Trysben 200 at 10 lb per acre in Region 2. Treatment applied May 20, 1958. Picture taken August 13, 1958. Note: Check area in background.

Fig. 5—Chlorea granular at 450 lb per acre applied April 22, 1958 on house track in Region 2. Picture taken August 21, 1958.

Fig. 6—Typical control obtained with MCP–Chlorea in Region 5. This area was treated during June 1956 with Radapon (dalapon)–Methoxone–Chlorox No. 2 at 17 lb and 77 gal conc. per acre and re-treated in June 1957 with Methoxone–Chlorea 800 at 185 gal solution per acre. Not re-treated during 1958. Picture taken October 1, 1958.

mixed with oil showed promise in these tests. Results of other materials tested in region 2 are included in Table 2A. FB 2, a new chemical not yet released for commercial use, was used in a test section in region 2. This chemical was applied alone and in combination with other materials to determine its value as a contact weed killer (Table 2B). The initial top kill provided with this chemical was very good, but regrowth occurred one month following application.

Granicide 2X used alone, and Herbicidol NP, alone and in combination with ATA–2,4–D, ammate, monuron, diuron and erbon, was applied in a test section in region 3. Johnson grass was the predominant species found in the area. These treatments provided a good initial top kill and reduced the density of Johnson grass. Specific results are included in Table 3.

A number of dry materials were used in yard areas in region 4. Results are shown in Tables 4A and 4B.

One of the most extensive long-term test sections followed covered 700 miles of branch line in region 5 (Table 5). The initial treatment was applied in June 1956 and re-treated in June 1957 and June 1958. The most outstanding treatment in these tests has been methoxone–chlorea (Fig. 6). This treatment has been consistent in providing good control for a two-year period.

A railroad in region 6 applied mixtures of sodium chlorate–sodium metaborate–monuron (Telvar W) at various rates during November 1957 for controlling vegetation on a branch line. Inspections this year reveal that the high rates of sodium chlorate and metaborate with a medium rate of monuron provided the most outstanding results. Annual species were controlled but deep-rooted perennial species survived (Refer to Table 6 for specific results).

Following is a summary of the results observed of various chemical treatments used by railroads on system-wide basis in six of the seven regions during 1958.

WEED CONTROL

Region 1

Methoxone–chlorea at the rates of 50 gal concentrate per acre (equivalent to 2 lb MCP, 87.5 lb sodium chlorate and 8 lb Telvar W) was used quite extensively on main and branch lines in region 1 during 1958. In one area, this treatment was applied during early June and inspected in August 1958. Species present were quackgrass, blue grass, foxtail, Mexican fireweed, bluestem, sweet clover, bindweed, upright spurge, horsetail and wild four-o'clock. This treatment provided very good control for the season. The estimated control was 90 to 95 percent on August 20. Only species surviving were horsetail, bindweed and bluestem.

In another area this treatment provided 95 percent control when applied during late May. Species in this area were smooth brome grass, blue grass, pigweed, Mexican fireweed and dandelion. The ballast was soil and cinders.

Another area was treated in June with 50 gal concentrate of MCP–chlorax plus 6 lb Telvar W. Vegetative species were similar to that found in other areas of region 1. Control on August 20 was estimated at 90 percent.

Methoxone–chlorax was used on main lines and yard areas in this region at 81 gal conc per acre. This material when applied during early June provided a good initial kill of all species after which some regrowth occurred late during the season. In one yard area the estimated percent control on September 30 was approximately 75 to 80 percent. Reinfestation was primarily with small grain seedlings.

A mixture of oil–Telvar W (monuron) applied at 100 gal and 8 lb, respectively, during June was effective in maintaining control for the season. Species in this area were blue grass, quackgrass, horsetail, timothy, ragweed, dock, sweet clover, milkweed, aster and others. Control was approximately 85 percent on August 21.

Atlas D–11 was used on one railroad during late June at the rate of 242 gal solution per acre (equivalent to 40.7 lb arsenic trioxide per acre). This treatment provided a good initial top kill from two to four weeks, after which annuals began to reinfest the area. At the time of inspection on August 21 the area had considerable regrowth, but it was evident that the density of the vegetation had been reduced.

Ureabor was applied in a yard area at the rate of 400 lb per acre during May 1958. Species were perennial grasses, sow thistle, plantain, dandelion, marestail, wild barley and others. Results on July 22 were very good with approximately 90 to 95 percent control. A few plants of dandelion and plantain survived.

Chlorea Granular at 290 lb per acre was used in one yard area in region 1 during May 1958. Vegetative species found in this area were blue grass, foxtail, dropseed, Mexican fireweed, dandelion, pigweed, lovegrass and others. Control on September 30 was approximately 80 percent. It was evident that the rate used was low considering the fact that some species were surviving that are normally controlled with recommended rates of this material.

Region 2

System-wide treatments observed in this area were Methoxone (MCP)–chlorea, Nalco H–174 and Urox.

A combination of methoxone–chlorea at the rate of 50 gal concentrate (equivalent to 2 lb MCP, 87.5 lb sodium chlorate and 6 lb Telvar W) per acre was used on a

Fig. 7—Typical control obtained in yard areas with dry herbicides in Region 2. This yard was treated between tracks only during May 1957 with Urox 150 lb per acre. Picture taken September 27, 1958.

branch line during June in this region. Vegetative species found in this area were quackgrass, blue grass, slough grass, smartweed, smooth brome grass and others. This treatment provided very good results for the season. The estimated percent control on August 21 was approximately 80 to 95 percent. Only isolated bunches of smartweed and slough grass survived this treatment.

Nalco H–174 was applied in a yard area between rails only at 250 lb per acre during April 1958. Vegetation in this area consisted of Mexican fireweed, bindweed, blue grass, crabgrass, black medic, smartweed, prostrate spurge and dock. Control in July was approximately 85 to 90 percent.

Urox at 150 lb per acre was applied in one yard between tracks during May 1957 (Fig. 7). Vegetative species in this area were foxtail, Mexican fireweed, sandbur, crabgrass, witchgrass, Russian thistle, Muhlenbergia spp., upright spurge, sweet clover, alfalfa, ragweed, annual smartweed, and plantain. This treatment provided good results for two seasons. Some regrowth was present during the late summer of this year. Control was estimated to be 70 to 95 percent on September 10, 1958.

Region 3

Chlorate–chloride was used on one railroad at the rate of 60 gal concentrate per acre in a split application. The first treatment was applied during June and the second during August. Species found in this area were blue grass, orchard grass, sweet clover, cheat grass, rye grass, crabgrass, marestail, daisy fleabane, Johnson grass and some Bermuda grass. Results were very good when inspected during early September. There was evidence that each application provided a good initial top kill. Some regrowth occurred following the first treatment but was controlled with the second application.

Herbicidol NP at 82.5 gal conc per acre was applied on one area in this region during June 1958. The predominant species in this area was Johnson grass. Other species were trumpet vine, Bermuda grass, little barley, downy chess, Bracken fern, blackberry briars, wild lettuce, honey suckle, Kudzu, wild onion, manna grass, broomsedge, evening primrose, dogbane, dandelion, blue grass, ragweed, nut grass, black medic, smilax, daisy fleabane, sleepy catchfly, sweet clover, wild geranium, buttercup, peppergrass and curled dock. This treatment provided a good initial top kill and controlled most annual species. Johnson grass had reinfested the area when inspected during late October.

In another area two treatments of Herbicidol NP was used at the rate of 82.5 gal conc per acre for each treatment. The first treatment was applied during June and the second in August. Vegetative species were similar to those found where a single treatment was applied. Two applications of this material maintained fair control throughout the season. Each application provided a good initial top kill. Annual species were controlled and the density of Johnson grass was reduced.

Gamet D at 200 gal per acre was used in this region during June 1957 for the control of trumpet vine. This material produced a good top kill and maintained good control during the 1957 season. An inspection was made during May 1958 to determine the effectiveness of this material in producing root kill. Approximately 65 to 70 percent of the trumpet vine had resprouted at the time of this inspection. There were indications that practically all the trumpet vine had been killed 3 to 12 in beneath the surface of the soil and ballast. The resprouting that was occurring came from the root system of these plants.

Hexachloroacetone, 2 percent by volume, in 160 gal per acre of Cox Hykil oil was used during August 1957 in a spot treatment for the control of Johnson grass. An inspection 60 days following application revealed that only 10 percent of the Johnson grass was resprouting. An early spring inspection was made this year to determine the percentage of root kill. On May 8, 1958, approximately 45 percent of the Johnson grass root system was either killed or seriously damaged. Results on September 27 were very good with approximately 80 to 85 percent control. Some areas were re-treated during August 1958 with a combination of HCA in a weed and brush spray mixture (2.5 gal HCA in 100 gal mixture). This material was applied at the rate of approximately 200 gal mixture per acre. This second treatment provided a very good top kill.

One yard area in this region was treated twice during 1958 with sodium arsenite at the rate of 60 gal conc per acre. The first application was made during June and the second in August. Vegetative species consisted of blue grass, nut grass, cheat grass, crabgrass, rye grass, dock and other grasses. Results were excellent when inspected on September 2, 1958. No regrowth was evident.

Nalco H–174 was used in another yard during 1957 and 1958 in region 3. The initial treatment was made in April 1957 at the rate of 400 lb per acre. A re-treatment was applied during April 1958 using 300 lb per acre. Vegetative species found in this area were nut grass, cheat grass, prostrate spurge, marestail, wild lettuce, Johnson grass, bitter weed, dandelion, peppergrass and crabgrass. Control when inspected on June 12, 1958 was approximately 95 percent. Nut grass was the only resistant species. According to a railroad representative, there was approximately 20 to 25 percent regrowth on November 12, 1958. Of this, 90 percent was nut grass, nine percent crabgrass and one percent other species.

In another area, Nalco H–174 was applied during April 1958 at the rate of 400 lb per acre between tracks and at 300 lb per acre between rails. Vegetative species were

similar to other areas treated with Nalco H–174. Results were very good when inspected during June.

Ureabor at 870 lb per acre was applied in a yard area during March 1957. Vegetative species found in this area were Johnson grass, prostrate spurge, crabgrass, ragweed, marestail, wild lettuce, cheat grass and bitter weed. Results 15 months following application were very good.

Another yard area in this region was treated between tracks with Concentrated Borascu at the rate of 6 to 7 lb per 100 sq ft. Vegetative species in this area were crabgrass, marestail, Johnson grass, nut grass, ragweed, wild lettuce, prostrate spurge, cheat grass and bitter weed. Results were very good when inspected June 12, 1958.

Region 4

Three treatments of Radapon–2,4–D at 20 lb and 4 lb per acre, respectively, were used on a main line in this region. The first application was made May 1, the second June 15 and the third August 20. Vegetative species found in this area were Bermuda grass, nut grass, sandbur, vasey-grass, Spanish needle, crabgrass, marestail, upright spurge, Florida pusley and bunch grass. Control was very good when inspected September 3, 1958. There was evidence that some annuals had reinfested the area following the second application but these had been killed with the third treatment. Some bunch grass was surviving.

One railroad used Nalco H–174 at rates of 280 lb to 480 lb per acre in 18-in and 24-in bands along the ballast toe line on a main line. These treatments were applied during April 1958. Vegetative species found in this area were Bermuda grass, sandbur, Spanish needle, upright spurge, crabgrass, bunch grass, marestail, nut grass and Florida pusley. Results were very good when inspected on September 3, 1958. Some Bermuda grass was encroaching along the edge of the treated area but other species were controlled. Estimated control ranged from 80 to 95 percent.

Region 5

Methoxone–chlorax at 81 gal conc per acre was applied on main lines of one railroad in this region during 1958. Vegetation consisted of brome grass, blue grass, quack grass and annuals. This treatment provided good initial kill of all species when applied during June. Some reinfestation occurred during the late summer with perennial grasses and annuals.

Region 6

One railroad used Monobor–chlorate No. 2 at 112 gal conc per acre during November 1957. Vegetation in this area consisted of Johnson grass, Indiangrass, big bluestem, little bluestem, Bermuda grass, silver bluestem, purple nightshade, Carolina horsenettle, prostrate spurge, upright spurge, sideoats grama, aster, prairie threeawn, buffalo-bur and Mexican fireweed. This treatment provided fair results when inspected during May 1958. Annual species were controlled but perennial species were reinfesting the area.

Granicide 2X was also used in this same area during November 1957. Vegetative species were similar to those found in areas where Monobor–chlorate No. 2 was applied. Control was fair when inspected during May 1958. Some perennials were reinfesting the area. However, this treatment appeared to be more effective in controlling Johnson grass than Monobar–chlorate No. 2.

Fig. 8—Brush control obtained from a treatment of 2,4–D and 2,4,5–T in Region 3 one year following application. Treatment was applied during June 1957 using off-track equipment. Picture taken July 10, 1958. Note: Treated under the pole line only.

BRUSH CONTROL

Low-volatile ester formulations of 2,4–D—2,4,5–T continue to be used quite extensively for controlling brush in all regions, with Ammate being substituted for the phenoxy compounds in areas adjacent to crops or in states where the use of phenoxy compounds are prohibited. It is usually the practice for railroads to apply these materials with on-track equipment; however, one railroad has employed the use of off-track equipment in applying chemicals for brush control during the past two years. The results obtained from this type of application have been outstanding but expensive.

Several test sections using dry granular and pelletized materials have been established in three of the seven regions during the 1958 season. These materials are usually slow reacting and their effectiveness cannot be determined in one season. Results justify further evaluation of these products. Table 7 includes the results obtained in brush control tests on three railroads in three regions, one of which was an aerial application.

Following is a summary of the results observed in 1958 of brush treatments used by railroads.

Region 2

A low-volatile ester formulation of 2,4–D—2,4,5–T (50:50 mixture) was used by one railroad during August 1957 at the rate of 2 to 3 gal conc per acre. Vegetative species found in this area were locust, elm, willow, sumac, cedar, wild plum, sycamore, sassafras and elderberry. The initial top kill was very good. Results during July 1958 were good with some resprouting of locust. Other species appeared to be controlled.

Applications using 2,4–D—2,4,5–T ester at 2.2 gal conc per acre and Ammate at 300 gal sol per acre (equivalent to 186 lb) were observed during July in this region. Predominant species in the area treated with 2,4–D—2,4,5–T were locust and elm. In areas treated with Ammate the predominant species was elm. Other species in these areas were sumac, oak, willow, sycamore, sassafras, elderberry, persimmon, sweet gum, wild plum, cedar and trumpet vine. These areas will be inspected early next spring to determine the effectiveness of these treatments.

Region 3

Results of brush control chemicals applied during June 1957 with off-track equipment were observed in this region. Two formulations were used; one contained 2 lb per gal 2,4–D and 2 lb per gal 2,4,5–T, and the other, 1⅓ lb per gal 2,4–D and ⅔ lb per gal 2,4,5–T. Both formulations were applied in an oil–water emulsion using 10 gal oil per 100 gal solution and applied at approximately 2 to 3 gal conc per acre. Vegetation consisted of sumac, sassafras, elm, sycamore, wild plum, oak, maple, sweet gum, walnut and honeysuckle. The initial kill was very good three months following application. Results 15 months after treatment were very good (Fig. 8). No differences were noted in response of the brush to these two formulations. Ash was resistant and some sprouting of sumac and elm was occurring. However, the estimated percent control of all species on August 29, 1958, was 85 to 90 percent.

Another railroad in this region used 2,4–D—2,4,5–T at 2 to 3 gal conc per acre, with Ammate at 180 lb in 300 gal water per acre substituted in areas adjacent to crops. These treatments were applied during August 1958. Vegetation consisted of sumac, sassafras, elm, oak, persimmon, pine, wild plum, trumpet vine and honeysuckle. The initial top kill of all species was very good when inspected on October 22, 1958. This area should be inspected during early spring to determine the effectiveness of these treatments.

TABLE 1A—RESULTS OF CHEMICAL TREATMENTS APPLIED ON TEST AREAS IN REGION 1

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Chlorea [1]	489 lb	May 8–9, 1957	Avg Max Temp: 1957—May—69.2°, June—76.8°, July—84.7°, Aug.—78.5°, Sept.—69.6°, Oct.—57.0°, Nov.—39.5°, Dec.—33.1°. 1958—Jan.—28.6°, Feb.—24.4°, Mar.—40.5°, Apr.—58.1°, May—73.7°, June—72.9°, July—79.1°, Aug.—80.6°, Sept.—73.2°. Precipitation: 1957: May—3.91", June—4.22", July—6.28", Aug.—5.01", Sept.—1.99", Oct.—1.50", Nov.—1.42", Dec.—0.21". Precipitation: Annual—1957—28.31", 1958—Jan.—0.25", Feb.—0.06", Mar.—0.36", Apr.—2.68", May—1.18", June—2.52", July—3.74", Aug.—3.10", Sept.—1.39".	Foxtail, smooth brome grass, Panicum spp., sandbur, prostrate spurge, Russian thistle, quackgrass, small grain, mallow, blue grass, pigweed and others.	90	95	1957 Results—Good kill. Some regrowth of green foxtail grass and few plants of prostrate spurge. 1958 Results—Some annuals came in during early spring prior to re-treatment. The 1958 treatment eliminated most species except Panicum spp. Very good control on Sept. 29.
Retreated with							
Chlorea [2]	340.4 lb	June 27, 1958					
Chlorea [2]	277.7 lb	May 8–9, 1957	"	"	85	88	1957 Results—Good kill. Minor regrowth of foxtail grass, prostrate spurge, sandbur. 1958 Results—Some annual species reinfested area during early spring prior to re-treatment. The 1958 treatment provided good control. Panicum spp. was resistant to this treatment.
Re-treated with							
Chlorea [2]	340.4 lb	June 27, 1958					
Ureabor [3]	435 lb	May 8–9, 1957	Avg Max Temp: 1957—May—69.2°, June—76.8°, July—84.7°, Aug.—78.5°, Sept.—69.6°, Oct.—57.0°, Nov.—39.5°, Dec.—33.1°. 1958—Jan.—28.6°, Feb.—24.4°, Mar.—40.5°, Apr.—58.1°, May—73.7°, June—72.9°, July—79.1°, Aug.—80.6°, Sept.—73.2°. Precipitation: 1957: May—3.91", June—4.22", July—6.28", Aug.—5.01", Sept.—1.99", Oct.—1.50", Nov.—1.42", Dec.—0.21". Precipitation: Annual—1957—28.31", 1958—Jan.—0.25", Feb.—0.06", Mar.—0.36", Apr.—2.68", May—1.18", June—2.52", July—3.74", Aug.—3.10", Sept. 1.39".	Foxtail, smooth brome grass, Panicum spp., sandbur, prostrate spurge, Russian thistle, quackgrass, small grain, mallow, blue grass, pigweed and others.	85	84	1957 Results—Good control. Some regrowth of foxtail grass, prostrate spurge, Russian thistle and Panicum spp. 1958 Results—Control was good at end of season. A few annual species such as prostrate spurge, sandbur and mallow were present during late August and Sept. Panicum spp. was resistant but its growth appeared to be retarded and some plants showed signs of injury from the chemical.
Re-treated with							
Ureabor	435 lb	June 10–15, 1958					

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Naleo [illegible] Not re-treated	250 lb	May 9, 1957	"	"	70	70	1957 Results—Very good control during 1957. Few plants of Panicum spp. survived. 1958 Results—This treatment maintained good control until the late summer at which time annuals began to reinfest the area. These annuals were prostrate spurge, green foxtail grass, sandbur, pigweed and mustard. The density of these annuals was sparse but their growth was rank. Panicum spp. was surviving but its growth was confined to isolated bunches.
Urox [5] Not re-treated	100 lb	May 16, 1957	"	"	60	85	1957 Results—Very good control. Soil practically sterile. 1958 Results—The treatment maintained good control until late summer after which annual species reinfested the area. These annuals were primarily prostrate spurge, foxtail, pigweed, Russian thistle and lovegrass. Panicum spp. was resistant to this treatment but only a few isolated bunches were present in this test. The reason for a higher rating during Sept. is unexplainable unless some of the annuals had been disturbed, killed by a light frost or their root zone reached the chemical level in the soil.
Urox Re-treated with Urox	100 lb 100 lb	May 16, 1957 June 10, 1958	"	"	85	95	1957 Results—Very good control. Soil practically sterile. 1958 Results—This treatment maintained good control throughout the 1958 season. A few annuals such as prostrate spurge and pigweed were present during the Aug. inspection but were not present 6 weeks later. A few plants of Panicum spp. survived.

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Urox Re-treated with Urox	100 lb 75 lb	May 16, 1957 June 10, 1958	"	"	95	95	1957 Results—Very good control. Soil practically sterile. 1958 Results—This treatment maintained very good control throughout the 1958 season. There were a few isolated plants of prostrate spurge that came in late during the summer. A few isolated clumps of Panicum spp. grass survived but its growth had been retarded and it showed signs of injury.
Urox Re-treated with Urox	100 lb 60 lb	May 16, 1957 June 10, 1958	"	"	98	95	1957 Results—Very good control. Soil practically sterile. 1958 Results—This treatment maintained very good control during the 1958 season. There was no apparent difference in this treatment and the area re-treated with 75 lb.
Nalco H-174 Not re-treated	250 lb	May 9, 1957	"	"	73	60	1957 Results—Very good control. Soil practically sterile. 1958 Results—This treatment maintained good control during the 1958 season until late summer. Annuals reinfesting this area were prostrate spurge, and foxtail. Panicum spp. was resistant in this test.
Urox Not re-treated	150 lb	May 16, 1957	"	"	80	75	1957 Results—Good control when inspected Aug. 15, 1957. Some regrowth of foxtail and Panicum spp. 1958 Results—Maintained control during the 1958 season. Annuals such as foxtail, prostrate spurge, crabgrass and fireweed infested this area during late summer. Panicum spp. resistant.

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Urox	150 lb	May 16, 1957	"	"	75	75	1957 Results—Good control, some regrowth of foxtail and Panicum spp. 1958 Results—Good control until late summer at which time annuals reinfested the area. Panicum spp. resistant.
Re-treated with Urox	25 lb	June 10, 1958					
Urox	150 lb	May 16, 1957	"	"	95	95	1957 Results—Good control. Some regrowth of foxtail and Panicum spp. 1958 Results—Maintained very good control. Some prostrate spurge and foxtail present during late summer.
Re-treated with Urox	50 lb	June 10, 1958					
Urox	150 lb	May 16, 1957	"	"	95	95	1957 Results—Good control. Some regrowth of foxtail and Panicum spp. 1958 Results—Very good control with a few annuals present late in season.
Re-treated with Urox	75 lb	June 10, 1958					
Urox	75 lb	June 10, 1958	"	"	30	40	Treated during 1958 only. Heavy growth during 1957 season. Treatment not sufficient to eliminate all vegetation in 1958. Annuals such as foxtail, crabgrass and fireweed present.
Chlorea [1]	625 lb	May 8–9, 1957	"	"	75	92	1957 Results—Good control. Some regrowth of prostrate spurge. Few plants Panicum spp. survived. 1958 Results—Considerable regrowth during mid-summer. Chemical became progressively better throughout the season. Species present were quackgrass, fireweed, crabgrass and green foxtail.
Re-treated with Chlorea [2]	340.4 lb	June 27, 1958					

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Chlorea[2]	432.6	May 8-9, 1957	"	"	85	94	1957 Results—Good control. Few plants Panicum spp. survived.
Re-treated with Chlorea[2]	340.4 lb	June 27, 1958					1958 Results—Some regrowth occurred during spring with annual species but the 1958 treatment eliminated these species.
Ureabor	435 lb	May 9, 1957	"	"	92	90	1957 Results—Good control all species except few plants Panicum spp. survived.
Re-treated with Ureabor	435 lb	June 10–15, 1958					1958 Results—Maintained good control throughout season. Few scattered plants of foxtail, fireweed and Russian thistle came in late during season.
Radapon[6]	6 gal	June 4, 1958	Avg Max Temp: 1958—Jan.—28.6°, Feb.—24.4°, Mar.—40.5°, Apr.—59.1°, May—73.7°, June—72.9°, July—79.1°, Aug.—80.6°, Sept.—73.2°. Precipitation—Annual—1957—28.31", 1958—Jan.—0.25", Feb.—0.06", Mar.—0.36", Apr.—2.68", May—1.18", June—2.52", July—3.74", Aug.—3.10", Sept.—1.39".	Blue grass, dock, quackgrass, Mexican fireweed, lambsquarters, mustard, knotweed, wild buckwheat, Jim Hill mustard, red root pigweed, pigeon grass, Pennsylvania smartweed, Hare's ear mustard, ragweed, marsh elder, fanweed, and small grain.	75	30	Good control through August after which the area was reinfested with annuals and small grains.
Kuron[7]	2 gal						
Radapon	10 gal	June 4, 1958	"	"	60	25	Provided good initial kill. Annuals and small grain reinfested area late during summer. Some quackgrass present but mostly annuals.
2,4-Dow Weed Killer Formula 40[8]	2 gal						

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Radapon Baron[9] 2,4-Dow Weed Killer Formula 40	4 gal 5 gal 1 gal	June 4, 1958	"	"	95	75	Maintained good control until late summer. Regrowth consisted primarily of spilled grain. This is difficult to keep under control because the large quantity of grain spilled often results in the small grain growing in its own body. Also some reinfestation with fireweed and wild buckwheat.
Garlon[10]	6 gal	June 4, 1958	"	"	70	30	Provided good initial kill. Heavy reinfestation of small grain during late summer. Some annuals germinated late in the season. These were foxtail, fireweed and pigweed.
Radapon Simazine 50W[11] 2,4-Dow Weed Killer Formula 40	5 gal 5 lb 1 gal	June 4, 1958	"	"	80	60	Maintained good control until late summer. Reinfested primarily with small grain. Some germination of fireweed and pigweed late in summer.
Radapon Telvar W[12] 2,4-Dow Weed Killer Formula 40	5 gal 10 lb 1 gal	June 4, 1958	"	"	95	50	Provided good control until late summer. Heavily reinfested with spilled small grain.
Garlon	4 gal	June 4, 1958	"	"	65	30	Provided good initial kill. Heavily reinfested with small grain and annuals during late summer.
MCP-Chlorax[13] Simazine 50W	70 gal conc. 7.14 lb	June 18, 1958	Avg Max Temp: 1958—Jan.—26.5°, Feb.—22.9°, Mar.—39.0°, Apr.—57.0°, May—70.7°, June—71.1°, July—78.7°, Aug.—79.2°, Sept.—70.5°. Precipitation—Annual—1957—32.45", 1958—Jan.—0.69", Feb.—0.23", Mar.—0.69", Apr.—2.03", May—2.05", June—2.25", July—2.63", Aug.—6.95", Sept.—4.97".	Quackgrass, blue grass, foxtail, fireweed, dandelion, crabgrass, flax and small grain.	.....	85	Inspected Sept. 30, 1958. Provided good control for the season. Some regrowth of quackgrass and a few clumps of blue grass. Also some germination of flax, crabgrass, foxtail and small grain.

TABLE 1A (Continued)

Treatment	Rate Applied Per Acre	Date Applied	Weather	Type of Vegetation	Percent Control		Remarks
					Aug. 20, 1958	Sept. 29, 1958	
Chlorea [2]	435 lb	May 23, 1958	Avg Max. Temp: 1958—Jan.—22.7°, Feb.—22.5°, Mar.—37.6°, Apr.—55.0°, May—68.2°, June—68.8°, July—76.2°, Aug.—77.4°, Sept.—66.4°. Precipitation—Annual—1957—25.89". 1958—Jan.—0.29", Feb.—0.11", Mar.—0.14", Apr.—0.88", May—2.06", June—5.21", July—2.03", Aug.—2.20", Sept.—2.38".	Quackgrass and blue grass.	-------	92	Inspected Sept. 30, 1958. Provided good seasonal control. Few sprigs of quackgrass surviving.

[1]Chlorea—Sodium chlorate 40%; metaborate 57%; (CMU) 3-(p-chlorophenyl)-1, 1-dimethylurea 1%.
[2]Chlorea—Sodium chlorate 40%; metaborate 54%; (CMU) 3-(p-chlorophenyl)-1, 1-dimethylurea 2.4% (Technical).
[3]Ureabor—Disodium tetraborate pentahydrate 63.2%; disodium tetraborate decahydrate 30.8%; (CMU) 3-(p-chlorophenyl)-1, 1-dimethylurea 4%.
[4]Nalco H-174—Sodium tetraborate 83%; (CMU) 3-(p-chlorophenyl)-1, 1-dimethylurea 8%.
[5]Urox—(CMU) 3-(p-chlorophenyl)-1, 1-dimethylurea and trichloroacetate 22%.
[6]Radapon—2,2 dichloropropionic acid 4 lb per gal 78% dalapon sodium salt.
[7]Kuron—Low volatile propylene glycol butyl ether ester, 2-(2,4,5-Trichlorophenoxy) propionic acid 4 lb acid equiv. per gal conc.
[8]2,4-Dow Weed Killer Formula 40—Alkanolamine salts of 2,4-Dichlorophenoxyacetic acid 4 lb acid equiv. per gal.
[9]Baron (erbon)—2,(2,4,5-trichlorophenoxy) ethyl 2,2 dichloropropionate, 4 lb per gal.
[10]Garlon—Contains diethylene glycol bis 2,2 dichloropropionate and 2-(2,4,5-trichlorophenoxy) propionic acid Propylene glycol butyl ether esters.
[11]Simazine 50W—2-chloro-4, 6-bis-(ethylamino)-s-triazine 50%.
[12]Telvar W—3-(chlorophenyl)-1, 1-dimethylurea 80%.
[13]MCP (Methoxone)-Chlorax—Sodium chorate 16.3%, sodium metaborate 9.1%, (MCP) 2-methyl-4-chlorophenoxyacetic acid .2%, inert ingredient 74.4%.

Table 1B—Results of Chemical Treatments Applied on Test Areas in Region 1

Size of Test Plots—Test No. 1—27 ft by 404 ft or ¼ acre, 20 ft check area between plots; Test No. 2—27 ft by 202 ft or ⅛ acre, 20 ft check area between plots.
Type of Vegetation—Test No. 1—Burdock, Canada thistle, clover, dandelion, grasses, horsetail, mouse eared chickweed, perennial grasses, pigweed, plantain, ragweed, red clover, sheep sorrel, sow thistle, strawberry, vetch and yarrow.
Test No. 2—Alder, blue weed (blue devil) burdock, cherry, clover, dandelion, fern, goldenrod, grasses, horsetail, milkweed, pigweed, ragweed, soft maple, strawberry, sumac seedling, sweet clover, yellow toadflax, and vetch.
Type of Ballast—Cinder, soil and gravel.
Date of Application—Test No. 1—May 21, 1958; Test No. 2—May 22, 1958.
Weather Data—Mean Temperature: 1958—Jan.—20°, Feb.—12°, March—33°, Apr.—45°, May—52°, June—60°, July—69°, Aug.—68°.
Precipitation—Annual—1957—37.4". 1958—Jan.—3.4", Feb.—5.2", March—2.0", Apr.—2.0", May—2.4", June—2.9", July—6.4", Aug.—3.99".
Date of Inspection—July 22, 1958.

Treatment	*Rate Applied Per Acre*	*Percent Concentration of Vegetative Species*				*Percent Control*				*Remarks*
		Test 1		*Test 2*		*Test 1*		*Test 2*		
		B-L[1]	*Gr*[2]	*B-L*	*Gr*	*B-L*	*Gr*	*B-L*	*Gr*	
Ureabor[3]	400 lb	60	40	10	90	93	99	80	88	Test No. 1—Good control all species except dandelion and plantain. These species were chlorotic and show signs of injury. Test No. 2—Some blue grass, milkweed and yellow toadflax surviving.
Chlorea Granular[4]	350 lb	20	80	10	90	98	98	95	95	Very good control in both test areas.
Granular Simazine[5]	200 lb	50	50	15	85	90	98	85	85	Test No. 1—Few dandelion plants surviving but were severely injured and appear to be dying. Test No. 2—Some blue grass and milkweed surviving but were injured. Some milkweed plants were killed.
Telvar W[6]	20 lb	90	10	50	50	95	98	95	93	Test No. 1—Dandelion and plantain surviving.
Trysben 200[7]	3 gal									
Calmix (pellets)[8]	220 lb	20	80	40-50	50-60	83	93	95	93	Test No. 1—Dandelion and plantain surviving. Dandelion more susceptible than plantain. Test No. 2—Yellow toadflax and bindweed surviving.
Nalco H-174[9]	250 lb	20	80	40	60	83	98	88	90	Test No. 1—Bindweed surviving. Some plants had leaves showing chlorosis. Test No. 2—Milkweed and some grasses surviving. However, grasses were injured.

[1]Broad-leaved Species.
[2]Grasses.
[3]Ureabor—Disodium tetraborate pentahydrate 63.2%; disodium tetraborate decahydrate 30.8%; Boron trioxide (B_2O_3) equivalent 11.4%; Boron B 12.86% 3-(p-chlorophenyl)-1, 1-dimethylurea 4%.
[4]Chlorea Granular—Sodium chlorate 40%; sodium metaborate 54%; 3-(p-chlorophenyl)-1, 1-dimethylurea 2.4% (Technical).
[5]Granular Simazine—2-chloro-4,6-bis-(ethylamino)-s-triazine 5%.
[6]Telvar W—(monuron)—3-(p-chlorophenyl)-1, 1-dimethylurea 80%.
[7]Trysben 200—dimethylamine salt of Trichlorobenzoic acid 24.8%; Dimethylamine salt of other Polychlorobenzoic acid 1.3%; contains 2 lb trichlorobenzoic acid equivalent per gal.
[8]Calmix (pellets)—3-(p-chlorophenyl)-1, 1-dimethylurea (CMU 80%) 13% or 10.4% Technical; 2,1-Dichlorophenoxyacetic acid 8%.
[9]Nalco H-174—Sodium tetraborate 83%; 3-(p-chlorophenyl)-1, 1-dimethylurea 8%.

TABLE 2A—RESULTS OF CHEMICAL TREATMENTS APPLIED ON TEST AREAS IN REGION 2

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Chlorea Granular [1]	453.77 lb	Apr. 22, 1958	Avg Max Temp: 1958—Jan.—30.1°, Feb.—26.1°, Mar.—40.0°, Apr.—59.6°, May—74.3°, June—75.3°, July—81.7°, Aug.—84.6°, Sept.—77.0°. Precipitation: Annual—1957—29.45". 1958—Jan.—0.20", Feb.—0.27", Mar.—0.26", Apr.—3.73", May —, June—1.89", July—4.73", Aug.—1.34", Sept.—0.99".	Smooth brome grass, blue grass, quackgrass, field bindweed, milkweed, western wheat grass, ground cherry, wild rose, Mexican fireweed, dandelion, slough grass, smartweed, wild four-o'clock, Cyprus spp., pigweed, dogbane, wild licorice, bull thistle, dock, horsetail, hedge bindweed, goldenrod, foxtail, whorled milkweed, ragweed, sow thistle, big blue stem, upright spurge, nightshade and Canada thistle.	93	Inspected August 21, 1958. Very good control. Excellent kill on grasses. Some scattered plants of deep-rooted perennials surviving. These were milkweed, dandelion, smartweed, field bindweed, ground cherry, wild rose, and whorled milkweed.
Chlorea Granular	386 lb	Apr. 22, 1958	"	"	73	Inspected Aug. 21, 1958. This treatment applied on branch line heavily infested with grasses and deep-rooted perennial broad-leaved species. Grasses and shallow rooted broad-leaved species controlled. Deep-rooted species were resistant. These species were primarily smartweed, milkweed, wild rose and wild licorice. Their infestation was dense in some spots and sparse in others. Other species listed were sparsely scattered throughout the test area.
Ureabor [2]	514.7 lb	Apr. 22, 1958	"	"	65	Inspected Aug. 21, 1958. This treatment was applied on a branch line heavily infested with grasses and deep-rooted broad-leaved perennial species. Controlled grasses and annual species. Heavy spots of smartweed, wild rose, milkweed and Canada thistle surviving which considerably influenced the rating.

TABLE 2A (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Nalco H-174[3]	286.5 lb	Apr. 22, 1958	"	"	78	Inspected Aug. 21, 1958. This treatment was applied on a branch line heavily infested with grasses and deep-rooted broad-leaved perennial species. Very good control of grasses and annual species. Deep-rooted broad-leaved species were resistant. They were scattered throughout the test area.
Baron[4] Agronyl-R Oil[5]	7.7 gal 92.3 gal	May 21, 1958	Avg Max Temp: 1958—Jan.—28.2°, Feb.—25.0°, Mar.—42.7°, Apr.—59.9°, May—75.5°, June—74.4°, July—80.6°, Aug.—84.4°, Sept.—74.8°. Precipitation: Annual—1957—32.61". 1958—Jan.—0.55", Feb.—0.28", Mar.—0.52", Apr.—1.90", May—2.24", June—3.41", July—5.31", Aug.—2.51", Sept.—2.40".	Foxtail, sandbur, Mexican fireweed, field bindweed, witchgrass, wild four-o'clock, burdock, lovegrass, prostrate spurge and crabgrass.	90	Inspected Aug. 13, 1958. Very good control Some wild four-o'clock, crabgrass and Mexican fireweed reinfesting the test area.
Telvar W[6] Agronyl-R Oil	10 lb 100 gal	May 21, 1958	"	"	99	Inspected Aug. 13, 1958. Excellent control. Only a wild four-o'clock plant in the test area.
Baron Agronyl-R Oil	7.7 gal 92.3 gal	May 21, 1958	"	"	80	Inspected Aug. 13, 1958. Some annuals reinfesting the area. These include foxtail, lovegrass, Mexican fireweed, prostrate spurge, sandbur, and witchgrass.
Simazine 50W[7] Agronyl-R Oil	10 lb 100 gal	May 21, 1958	"	"	95	Inspected Aug. 13, 1958. Very good control.
Agronyl-R Oil	100 gal	May 21, 1958	"	"	Clean	Inspected Aug. 13, 1958. No vegetation on this test area originally.
Trysben 200[8]	10 lb	May 20, 1958	"	Bouncing bet.	95	Inspected Aug. 13, 1958.

TABLE 2A (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Trysben 200	5 lb	May 20, 1958	"	Field bindweed.	99	Inspected Aug. 13, 1958.
Trysben 200	10 lb	May 20, 1958	"	Field bindweed	99	Inspected Aug. 13, 1958.
Telvar W Oil	10 lb 100 gal	May 27, 1958	Avg Max Temp: 1958—Jan.—27.8°, Feb.—24.6°, Mar.—42.7°, Apr.—60.6°, May—74.1°, June—73.1°, July—78.3°, Aug.—81.5°, Sept.—73.0°. Precipitation: Annual—1957—32.00"; (1.60" below normal). 1958—Jan.—1.02", Feb.—0.21", Mar.—0.46", Apr.—2.47", May 1.87", June—4.19", July—7.09", Aug.—3.70", Sept.—1.79".	Quackgrass, foxtail, dandelion, wild four-o'clock, goldenrod, milkweed, marestail, field bindweed, Mexican fireweed, daisy fleabane, sandbur, and lovegrass.	80	Inspected Aug. 13, 1958. Some spots of quackgrass surviving. Also, scattered plants of dandelion, milkweed, field bindweed, wild four-o'clock, goldenrod, sandbur and fireweed surviving.
Urox [9]	100 lb	Apr. 20, 1956	Avg Max Temp: 1957—Jan.—26.6°, Feb.—39.4°, Mar.—45.0°, Apr.—58.0°, May—67.9°, June—80.2°, July—85.3°, Aug.—82.1°, Sept.—73.0°, Oct.—59.6°, Nov. 47.3°, Dec.—41.8°. 1958—Jan.—31.5°, Feb.—26.7°, Mar.—41.0°, Apr.—60.4°, May—73.1°, June—74.1°, July—81.5°, Aug.—83.2°, Sept.—75.5°. Precipitation: 1957—Jan.—2.06", Feb.—1.77", Mar.—1.98", Apr.—5.09", May—3.21", June—5.94", July—8.98", Aug.—5.36", Sept.—1.08", Oct.—3.15", Nov.—2.72", Dec.—1.95". 1958—Jan.—1.12", Feb.—0.33", Mar.—0.33", Apr.—1.64", May—3.12", June—6.43", July—4.74", Aug.—2.51", Sept.—1.86".	Quackgrass, milkweed, bindweed, yellow toadflax, horsetail, wild carrot, dandelion, and prostrate spurge.	85	Inspected Sept. 10, 1958. Some field bindweed, milkweed, wild carrot and prostrate spurge surviving.
Urox Re-treated with Urox	100 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	90	Inspected Sept. 10, 1958. Some milkweed, horsetail, quackgrass and prostrate spurge surviving.

TABLE 2A (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Urox	125 lb	Apr. 20, 1956	"	"	85	Inspected Sept. 10, 1958. Some prostrate spurge, field bindweed, milkweed, quackgrass, and small grain seedlings reinfesting test area.
Urox Re-treated with Urox	125 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	98	Inspected Sept. 10, 1958. Milkweed and horsetail surviving.
Urox	150 lb	Apr. 20, 1956	"	"	85	Inspected Sept. 10, 1958. Some field bindweed, prostrate spurge, quackgrass, milkweed and lovegrass reinfesting area.
Urox Re-treated with Urox	150 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	97	Inspected Sept. 10, 1958. Milkweed and wild carrot surviving.
Urox	175 lb	Apr. 20, 1956	"	"	85	Inspected Sept. 10, 1958. Field bindweed, prostrate spurge, milkweed and lovegrass reinfesting area.
Urox Re-treated with Urox	175 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	97	Inspected Sept. 10, 1958. Field bindweed, dandelion, quackgrass and small grain seedlings reinfesting area.
Urox Re-treated with Urox	200 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	99	Inspected Sept. 10, 1958. Field bindweed surviving.
Urox	225 lb	Apr. 20, 1956	"	"	70	Inspected Sept. 10, 1958. Yellow toadflax resistant and makes up 95% of surviving vegetation. Other species reinfesting area were field bindweed, milkweed, wild carrot and quackgrass.
Urox Re-treated with Urox	225 lb 75 lb	Apr. 20, 1956 Spring, 1957	"	"	90	Inspected Sept. 10, 1958. Yellow toadflax, wild carrot and prostrate spurge reinfesting area. Quackgrass encroaching along edge of test area.

TABLE 2A (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Ureabor	435 lb	June 27, 1958	"	Quackgrass, wild barley, Mexican fireweed, sweet clover, peppergrass, wild lettuce, dandelion, white clover, sun flower, blue grass, plantain, smartweed, aster, dropseed, mustard, curled dock, bull thistle, goatsbeard, ragweed, prostrate spurge, wild four-o'clock, mint, timothy and black medic.	93	Inspected Nov. 6, 1958. Some dandelion surviving. Other species controlled.
DB-Granular [10]	978.75 lb	June 27, 1958	"	"	68	Inspected Nov. 6, 1958. Eliminated broad-leaved species. Blue grass and quackgrass survived.
XPI-12A [11]	435 lb	June 27, 1958	"	"	90	Inspected Nov. 6, 1958. Good on broad-leaved species.
XPI-12B [12]	435 lb	June 27, 1958	"	"	98	Inspected Nov. 6, 1958.
Ureabor	870 lb	June 27, 1958	"	"	95	Inspected Nov. 6, 1958.
XPI-12A	870 lb	June 27, 1958	"	"	95	Inspected Nov. 6, 1958.
XPI-12B	870 lb	June 27, 1958	"	"	99	Inspected Nov. 6, 1958.
Urox	125 lb	July 17, 1958	"	Blue grass, Mexican fireweed, crabgrass, prostrate spurge, smartweed and plantain.	95	Inspected Nov. 6, 1958.
HCA 2,4-D Furnace Oil	3 gal 1 gal 97 gal	July 17, 1958	"	Blue grass, crabgrass, Mexican fireweed and smartweed.	75	Inspected Nov. 6, 1958. Some blue grass surviving.
Urox	150 lb	July 17, 1958	"	Blue grass, crabgrass, Mexican fireweed, quackgrass, field bindweed, Canada thistle.	90	Inspected Nov. 6, 1958.
Arsenic Trioxide [13] +Calcium chloride	1500 lb	June 10, 1958	"	Willow, goldenrod, mint, wild parsnip, burdock, yarrow, blue grass and aster.	45	Inspected Nov. 6, 1958. Very little grass on this area originally. No effects on willow. Controlled approximately 90% of all broad-leaved weeds and 60% of grasses.

TABLE 2A (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Arsenic Trioxide----	1800 lb	June 10, 1958	"	Willow, goldenrod, mint, yarrow, Canada thistle, aster and blue grass.	70	Inspected Nov. 6, 1958. Very little grass on this area originally. Willow showing symptoms of injury. This treatment eliminated approximately 95% broad-leaved weeds and 98% grasses.
Arsenic Trioxide----	2000 lb	June 10, 1958	"	Blue grass, Canada thistle, goldenrod, milkweed, sunflower, quackgrass, and wild parsnip.	45	Inspected Nov. 6, 1958. Controlled approximately 50% broad-leaved weeds and 40% grasses. Canada thistle and blue grass resistant.
Arsenic Trioxide----	2200 lb	June 10, 1958	"	"	55	Inspected Nov. 6, 1958. Blue grass predominant species. Controlled approximately 80% broad-leaved weeds and 30% grasses. Canada thistle and blue grass resistant. Goldenrod intermediately susceptible.
Arsenic Trioxide----	2500 lb	June 10, 1958	"	"	70	Inspected Nov. 6, 1958. Controlled approximately 70% broad-leaved weeds and 70% grasses. Canada thistle resistant. Blue grass intermediately susceptible.

[1]Chlorea Granular—Sodium chlorate 40%; sodium metaborate 54%; 3-(p-chlorophenyl)-1, 1-dimethylurea 2.4% (Technical).
[2]Ureabor—Disodium tetraborate pentahydrate 63.2%; disodium tetraborate decahydrate 30.8%; 3-(p-chlorophenyl)-1,1-dimethylurea 4%.
[3]Nalco H-174—Sodium tetraborate 83%; 3-(p-chlorophenyl)-1,1-dimethylurea 8%.
[4]Baron—2-(2,4,5-trichlorophenoxy) ethyl 2,2 dichloropropionate, 4 lb per gal.
[5]Agronyl R Oil—Specific gravity 0.9652; pour point, F30-80 (low by special blends); flash point 220; viscosity S.V. @ 120 F sec. 40; initial boiling point 434; end point 760; percent aromatics 50% min.
[6]Telvar W—3-(p-chlorophenyl)-1,1-dimethylurea 80%.
[7]Simazine 50W—2-chloro-4, 6-bis-(ethylamino)-s-triazine 50%.
[8]Trysben 200—Dimethylamine salt of Trichlorobenzoic acid 24.8%, Dimethylamine salt of other Polychlorobenzoic acid 1.3%. Total active ingredients 26.1%.
[9]Urox—3-(p-chlorophenyl)-1,1-dimethylurea and trichloroacetate, 22%.
[10]DB-Granular—Disodium tetraborate pentahydrate 55%; disodium tetraborate decahydrate 35.5%; 2,4-Dichlorophenoxyacetic acid equivalent 7.5%.
[11]XPI-12A—Experimental material.
[12]XPI-12B—Experimental material.
[13]Arsenic Trioxide—As_2O_3 plus 2% calcium chloride.

Table 2B—Results of Chemical Treatments Applied on Test Areas in Region 2

Type of Vegetation: Yellow sweet clover, sunflower, field bindweed, quackgrass, foxtail, giant ragweed, red clover, marestail, Russian knapweed, Canada thistle, alfalfa, black medic, witchgrass, Mexican fireweed, milkweed, common ragweed, lambsquarters, wild buckwheat, prostrate spurge, dock, Cyprus spp., sandbur, bladder campion, upright spurge, timothy, tickle grass, dandelion, oats and daisy fleabane.
Date of Application: June 21, 1958.
Weather Data: Avg. Max. Temp.—1958—Apr.—60.4°, May—73.1°, June 74.1°, July—81.5°, Aug.—83.2°, Sept.—75.5°.
Precipitation—1958—Apr.—1.64″, May—3.12″, June—6.43″, July—4.74″, Aug.—2.51″, Sept.—1.86″.

Treatment	*Rate Applied Per Acre*	*Volume Applied Per Acre*	*Additive Per 100 gal*	*Percent Control*				*Remarks*
				June 27, 1958		*July 30, 1958*		
				B-L[1]	*Gr.*[2]	*B-L*	*Gr.*	
FB-2[3]	2 lb	150 gal	1 qt	83	72	17	20	Heavy regrowth. Surviving species quackgrass*, field bindweed*, foxtail, ragweed, lambsquarters, prostrate spurge, red clover and wild buckwheat.
FB-2	4 lb	150 gal	1 qt	96	86	13	37	Heavy regrowth field bindweed*, quackgrass*, and foxtail*. Other species reinfesting area alfalfa, black medic, red clover, witchgrass, wild buckwheat, prostrate spurge, Canada thistle, lambsquarters, dock and timothy.
FB-2	6 lb	150 gal	1 qt	95	91	40	52	Reinfested primarily with quackgrass*, field bindweed*, prostrate spurge* and witchgrass*. Other species foxtail, dock, Canada thistle, oats, wild buckwheat, ragweed, dandelion and sunflower.
FB-2 Telvar W[4]	2 lb 8 lb	150 gal	1 qt	90	73	80	77	Surviving species quackgrass*, Russian knapweed*, Canada thistle*, black medic*, witchgrass, field bindweed, foxtail, Mexican fireweed, dock, prostrate spurge and ragweed.
FB-2 Telvar W	4 lb 8 lb	150 gal	1 qt	80	80	63	68	Surviving species field bindweed*, quackgrass, witchgrass*, red clover, alfalfa and prostrate spurge.
FB-2 Telvar W	6 lb 8 lb	150 gal	1 qt	97	73	50	65	Reinfested primarily with field bindweed*, quackgrass* and Canada thistle*. Other surviving species milkweed, dock and witchgrass.
Chlorax[5] Telvar W	50 gal 6 lb	150 gal	----------	77	53	89	87	Surviving species quackgrass*, field bindweed*, Cyprus spp.*, dock, sweet clover, foxtail, sandbur, Canada thistle and witchgrass.
Atlas A[6]	15 gal	150 gal	----------	94	67	33	47	Heavy regrowth with field bindweed*, quackgrass*, prostrate spurge* and tickle grass. Other surviving species timothy, Mexican fireweed, bladder campion, dock, upright spurge, Canada thistle and milkweed.

TABLE 2B (Continued)

Treatment	Rate Applied Per Acre	Volume Applied Per Acre	Additive Per 100 gal	Percent Control				Remarks
				June 27, 1958		July 30, 1958		
				B-L[1]	Gr.[2]	B-L	Gr.	
Atlas A[6]	40 gal	150 gal	-	99	82	48	53	Heavy regrowth with field bindweed*, and quackgrass. Other species reinfesting area Mexican fireweed, foxtail, milkweed, alfalfa, witchgrass and prostrate spurge.

*Predominant species.
[1]Broad-leaved species.
[2]Grasses.
[3]FB-2—1:1' ethylene 2,2' dipyridylium dibromide.
[4]Telvar W—3-(p-chlorophenyl)-1,1-dimethylurea 80%.
[5]Chlorax—Sodium chlorate 18.2%, sodium metaborate** 10%, inert ingredient 71.8%.
**Equivalent to 1.67% boron as expressed as element boron.
[6]Atlas A—Arsenic trioxide (As_2O_3) 4 lb per gal conc.

Table 3—Results of Chemical Treatments Applied on Test Areas in Region 3

Size of Test Plot—Width—8 ft each side of roadbed beginning at end of ties. Length—2 miles. A mile check plot between each treatment.
Type of Vegetation—Predominant Species—Johnson grass, trumpet vine, Bermuda grass, Downy chess, Bracken fern, blackberry briars, little barley, wild lettuce, wild vetch, honey suckle and Kudzu.
Other species—wild onion, wild geranium, buttercup, crimson clover, manna grass, broomsedge, evening primrose, sweet clover, moth mullen, yellow trefoil or black medic, peppergrass, curled dock, dogbane, dandelion, sleepy catchfly, goldenrod, red sorrel, bull thistle, smilax, prickly lettuce, fleabane daisy, poison ivy, henbit, Kentucky bluegrass, ragweed and nutgrass.
Type of Ballast—Crushed slag.
Date of Application—First application—April 30, 1958, second application—August 13 and 26, 1958, third application—August 26, 1958.
Weather Data—Avg. Max. Temp: 1957—Jan.—50.0°, Feb.—50.1°, March—61.1°, April—77.2°, May—83.9°, June—89.8°, July—89.1°, Aug.—90.8°, Sept.—86.5°. Precipitation: Annual—1957—60.30″, 1958—Jan.—2.7″, Feb.—5.87″, March—4.91″, April—3.27″, May—1.03″, June—5.64″, July—5.29″, Aug.—3.16″, Sept.—4.84″.
Date Inspected—June 17, 1958 and October 22, 1958.

Treatment	*Rate Conc. Applied Per Acre*	*Date Applied*	*Percent Control*		*Remarks*
			June 17, 1958	*Oct. 22, 1958*	
Herbicidol-NP	82.5 gal	Apr. 30, 1958	70	40	Good initial top kill. Johnson grass predominant species. Density of Johnson grass reduced. Annual species controlled. Broad-leaved species recovering.
Re-treated with Granicide 2X	82.5 gal	Aug. 26, 1958			
Herbicidol-NP	82.5 gal	Apr. 30, 1958	70	65	Johnson grass predominant species. Good initial top kill. Density of Johnson grass reduced but some regrowth 6 in to 12 in high. Annual species controlled. Bermuda grass and broad-leaved species recovering.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 26, 1958			
Herbicidol-NP	36.3 gal	Apr. 30, 1958	40	50	Johnson grass predominant species. Good initial top kill. Density of Johnson grass reduced. Very good control broad-leaved species.
Re-treated with Herbicidol-NP+ATA+2,4-D	82.5 gal	Aug. 26, 1958			
Herbicidol-NP+Ammate	82.5 gal	Apr. 30, 1958	60	60	Johnson grass predominant species. Good initial top kill. Density of Johnson grass reduced. Annual species controlled.
Re-treated with Herbicidol-NP+Ammate	93.2 gal	Aug. 26, 1958			
Herbicidol-NP+Ammate	41.25 gal	Apr. 30, 1958	40	55	Johnson grass predominant species. Density of Johnson grass reduced. First treatment not as effective on both grasses and broad-leaved species as 82.5 gal conc. per acre. Second treatment controlled annuals and broad-leaved species.
Re-treated with Herbicidol-NP+Ammate	88.3 gal	Aug. 26, 1958			
Granicide 2X	82.5 gal	Apr. 30, 1958	70	70	Johnson grass predominant species. Good control grasses but some regrowth. Johnson grass stand reduced considerably. Bermuda grass top killed but regrowing.
Re-treated with Granicide 2X	93.2 gal	Aug. 26, 1958			

TABLE 3 (Continued)

Treatment	Rate Conc. Applied Per Acre	Date Applied	Percent Control		Remarks
			June 17, 1958	Oct. 22, 1958	
Herbicidol-NP+monuron	65.2 gal	Apr. 30, 1958	70	80	Johnson grass predominant species. Good control. Some Johnson grass surviving.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Re-treated with Herbicidol-NP	81.9 gal	Aug. 26, 1958			
Herbicidol-NP+monuron	82.5 gal	Apr. 30, 1958	70	60	Johnson grass predominant species. Good initial kill. Some Johnson grass surviving but its density was reduced and its growth retarded. Annuals controlled.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Re-treated with Herbicidol-NP	45.4 gal	Aug. 26, 1958			
Herbicidol-NP+erbon	80.7 gal	Apr. 30, 1958	70	40	Johnson grass predominant species. Good initial top kill. Density of Johnson grass reduced but some Johnson grass regrowing.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Herbicidol-NP+erbon	82.5 gal	Apr. 30, 1958	70	80	Johnson grass predominant species. Good control. Third treatment considerably increased over-all control. Density of Johnson grass reduced.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Re-treated with Herbicidol-NP	66 gal	Aug. 26, 1958			
Herbicidol-NP+diuron	64.4 gal	Apr. 30, 1958	70	----	Johnson grass predominant species. Good initial top kill. Diuron showing very little effects in June.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Herbicidol-NP+diuron	77.6 gal	Apr. 30, 1958	70	----	Johnson grass predominant species. Good initial top kill. Diuron showing very little effects in June.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			
Re-treated with Herbicidol-NP	45.4 gal	Aug. 26, 1958			
Herbicidol-NP+ATA	82.5 gal	Apr. 30, 1958	70	----	Johnson grass predominant species. Good initial top kill. Good control broad-leaved species such as trumpet vine and dogbane.
Re-treated with Herbicidol-NP	82.5 gal	Aug. 13, 1958			

Table 4A—Results of Chemical Treatments Applied on Test Areas in Region 3–4

Size of Test Plots—16½ ft wide and 130 ft long. A 10 ft check area between each test plot.
Type of Vegetation—Test 1—Johnson grass, Bermuda grass, nut grass, narrow leaf plantain, sweet clover, wild lettuce, primrose, horse nettle, peppergrass, bitterweed, dock, wild carrot, wild onion, false golden aster, upright spurge, mint, broomsedge, black medic, dandelion, marestail, crabgrass, bouncing bet, foxtail.
Test 2—Bermuda grass, Johnson grass, nut grass, false golden aster, vasey grass, sandbur, Florida pusley, crabgrass, marestail, prostrate spurge, dewberry, upright spurge, broomsedge, giant foxtail.
Test 3—Florida pusley, Bermuda grass, nut grass, vasey grass, upright spurge, tickle grass, crabgrass, maiden cane, dewberry.
Date of Application—Test 1—April 6, 1958, Test 2—April 7, 1958, Test 3—April 6, 1958.
Weather Data—Test 1—Avg. Max. Temp.—Jan.—48.5°, Feb.—48.1°, March—59.7°, Apr.—74.9°, May—83.6°, June—89.4°, July—89.0°, Aug.—90.3°, Sept.—85.6°. Precipitation—Annual—1957—59.77". 1958—Jan.—3.42", Feb.—5.14", March—3.03", Apr.—3.51", May—2.33", June—3.10", July—6.79", Aug.—1.98" Sept.—5.74".
Test 2—Avg. Max. Temp.—Jan.—53.5°, Feb.—56.2°, March—63.8° Apr.—76.7°, May—82.2°, June—88.6°, July—91.3°, Aug.—90.7°, Sept.—87.3°. Precipitation —Annual—1957—63.96". 1958—Jan.—3.17", Feb.—2.78", March—5.99", Apr.—6.44", May—4.19", June—5.56", July—6.52", Aug.—6.19", Sept.—3.02".
Test 3—Avg. Max. Temp.—Jan.—57.8°, Feb.—59.7°, March—68.8°, Apr.—79.3°, May—82.4° June—88.9°, July—91.1°, Aug.—90.2°, Sept.—88.9°. Precipitation —Annual—1957—54.29". 1958—Jan.—3.39", Feb.—3.74", March—3.38", Apr.—8.24", May—3.79", June—3.96", July—4.37", Aug.—4.67", Sept.—4.75".
Date Inspected—Test 1—June 12, 1958 and October 23, 1958; Test 2—September 4, 1958; Test 3—September 4, 1958.
Type of Ballast—Test 1—Soil and cinders; Test 2—Sandy soil; Test 3—Crushed rock ballast with sandy soil on edge of roadbed.

Treatment	*Rate Applied Per Acre*	*Percent Control*				*Remarks*
		Test 1		*Test 2*	*Test 3*	
		June 12	*Oct. 23*	*Sept. 4*	*Sept. 4*	
DWK 581		70	50	50	30	Test 1—Johnson grass susceptible, Bermuda grass, nut grass and plantain resistant. Crabgrass reinfested area late summer. Test 2—False golden aster and crabgrass predominant species Sept. 4. Nut grass, false golden aster and vasey grass resistant. Bermuda grass intermediate. Annuals such as crabgrass, Florida pusley and sandbur came in late summer. Test 3—Florida pusley, predominant species Sept. 4. Nut grass and vasey grass resistant. Bermuda grass intermediate. Florida pusley and upright spurge infested area during late summer.
(Telvar W	20 lb					
TCA	20 lb					
ATA	8 lb					
Inert	52 lb)					
DWK 582		80	40	50	30	Test 1—Bermuda grass, nut grass and plantain resistant. Johnson grass intermediate to susceptible. Crabgrass reinfested area late summer. Test 2—Crabgrass predominant species Sept. 4. False golden aster and marestail resistant. Bermuda grass intermediate. Crabgrass infested area late summer. Test 3—Florida pusley predominant species Sept. 4. Nut grass and vasey grass resistant. Florida pusley and tickle grass infested area late summer.
(Telvar W	20 lb					
TCA	20 lb					
Inert	60 lb)					
DWK 583		80	60	50	20	Test 1—Nut grass resistant to intermediate. Johnson grass intermediate. Bermuda grass intermediate to susceptible. Test 2—Bermuda grass intermediate. Florida pusley, crabgrass and prostrate spurge infested area late summer. Test 3—Vasey grass resistant. Bermuda grass intermediate. Florida pusley, crabgrass and upright spurge infested area late summer. Heavy with Florida pusley.
(Telvar W	20 lb					
ATA	10 lb					
Inert	70 lb)					

TABLE 4A (Continued)

Treatment	Rate Applied Per Acre	Percent Control				Remarks
		Test 1		Test 2	Test 3	
		June 12	Oct. 23	Sept. 4	Sept. 4	
DWK 584		80	55	75	40	Test 1—Nutgrass resistant to intermediate. Bermuda grass intermediate. Crabgrass infested area late summer. Test 2—Crabgrass predominant species Sept. 4. Dewberry, Johnson grass and nut grass resistant. Bermuda grass intermediate. Crabgrass, upright spurge and Florida pusley infested area late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass and maiden cane resistant. Florida pusley and crabgrass infested area during late summer.
(Telvar W	40 lb					
Inert	60 lb)					
DWK 585		65	35	40	30	Test 1—Bermuda grass predominant species Oct. 23. Approximately 40% Bermuda grass surviving June 12 and it reinfested area by Oct. 23. Nut grass resistant to intermediate. Broomsedge resistant, Johnson grass intermediate (sprigs). Test 2—Crabgrass predominant species Sept. 4. Nut grass, vasey grass and broomsedge resistant. Bermuda grass intermediate. Crabgrass, Florida pusley and giant foxtail infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Nut grass and vasey grass resistant. Florida pusley and upright spurge infested area during late summer.
(Simazine	20 lb					
TCA	20 lb					
ATA	8 lb					
Inert	52 lb)					
DWK 586		55	30	20	30	Test 1—Bermuda grass intermediate (approximately 40% surviving June 12) to resistant. Reinfested area by Oct. 23. Nut grass intermediate to resistant. Bouncing bet and horsenettle resistant. Sprigs Johnson grass intermediate. Test 2—Bermuda grass, vasey grass, broomsedge and dewberry resistant. Crabgrass, prostrate spurge and foxtail infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Maiden cane and dewberry resistant. Bermuda grass intermediate. Florida pusley and upright spurge infested area during late summer.
(Simazine	20 lb					
TCA	20 lb					
Inert	60 lb)					
DWK 587		35	20	40	30	Test 1—Bermuda grass resistant to intermediate (approximately 50% surviving June 17), nut grass, Johnson grass, false golden aster and three seeded mercury resistant. Foxtail and pigweed came in during the summer. Test 2—Vasey grass, broomsedge and dewberry resistant. Bermuda grass intermediate. Crabgrass, Florida pusley, foxtail and upright spurge infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass resistant. Bermuda grass intermediate. Florida pusley, upright spurge and crabgrass reinfested area during late summer.
(Simazine	20 lb					
ATA	10 lb					
Inert	70 lb)					

TABLE 4A (Continued)

Treatment	Rate Applied Per Acre	Percent Control				Remarks
		Test 1		Test 2	Test 3	
		June 12	Oct. 23	Sept. 4	Sept. 4	
DWK 588 (Simazine Telvar W Inert	 20 lb 20 lb 60 lb)	75	50	60	40	Test 1—False golden aster and sprigs Johnson grass resistant. Bermuda grass intermediate. Test 2—False golden aster and dewberry resistant. Bermuda grass intermediate. Crabgrass and prostrate spurge infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass, maiden cane and dewberry resistant. Florida pusley and upright spurge infested area during late summer.
DWK 589 (Simazine Telvar W ATA Inert	 20 lb 20 lb 8 lb 52 lb)	75	50	70	50	Test 1—Bermuda grass intermediate to susceptible, broomsedge resistant. Nut grass resistant and came in after other species were killed. Foxtail infested area during late summer. Test 2—Nut grass, false golden aster, horsetail and broomsedge resistant. Bermuda grass intermediate. Crabgrass and upright spurge infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass and maiden cane resistant. Bermuda grass intermediate. Florida pusley and upright spurge infested area during late summer.
DWK 5810 (Simazine Inert	 40 lb 60 lb)	60	40	30	30	Test 1—Bermuda grass intermediate to resistant (approximately 50% surviving June 12). It reinfested area by Oct. 23. Nut grass resistant. Johnson grass sprigs intermediate. Test 2—False golden aster, crabgrass and nut grass predominant species Sept. 4. False golden aster, nut grass and vasey grass resistant. Bermuda grass intermediate. Crabgrass, foxtail and Florida pusley infested area during late summer. Test 3—Florida pusley predominant species. Vasey grass and dewberry resistant. Heavy regrowth with Florida pusley and some crabgrass.
DWK 5811 (Simazine (TCA (Kuron (Inert	 20 lb 60 lb 10 lb 60 lb)	70	40	20	40	Test 1—Bermuda grass intermediate to resistant, (approximately 10% surviving June 12) but heavy regrowth Oct. 23. Broomsedge and bitterweed resistant. Test 2—Nut grass, Bermuda grass and Johnson grass predominant species Sept. 4. Nut grass and Johnson grass resistant. Bermuda grass intermediate. Crabgrass, sandbur, Florida pusley and goosegrass infested area during late summer. Test 3—Florida pusley predominant species. Dewberry resistant. Bermuda grass intermediate. Heavy regrowth Florida pusley and some crabgrass during late summer.

TABLE 4A (Continued)

Treatment	Rate Applied Per Acre	Percent Control				Remarks
		Test 1		Test 2	Test 3	
		June 12	Oct. 23	Sept. 4	Sept. 4	
DWK 5812		90	60	45	30	Test 1—Mint, sweet clover, nut grass and bitterweed resistant. Bermuda grass intermediate. Upright spurge infested area during summer. Test 2—Nut grass and Bermuda grass predominant species Sept. 4. Nut grass and vasey grass resistant. Bermuda grass intermediate. Crabgrass infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Bermuda grass and nut grass intermediate. Heavy regrowth Florida pusley and some upright spurge during late summer.
(Telvar W	20 lb					
TCA	100 lb					
Inert	80 lb)					
DWK 5813		90	45	30	30	Test 1—Bermuda grass intermediate to resistant. It reinfested area by Oct. 23. False golden aster resistant. Test 2—Vasey grass, Bermuda grass and nut grass predominant species Sept. 4. Vasey grass, Bermuda grass, nut grass and Johnson grass resistant. Crabgrass infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass, nut grass and dewberry resistant. Bermuda grass intermediate. Heavy regrowth Florida pusley. Some crabgrass and upright spurge infested area during late summer.
(Simazine	20 lb					
TCA	100 lb					
Inert	80 lb)					
DWK 5811		90	75	30	40	Test 1—Nut grass, horsenettle and isolated plants of broomsedge surviving. Test 2—Nut grass heavy and predominant species Sept. 4. Vasey grass and nut grass resistant. Bermuda grass intermediate. Test 3—Florida pusley predominant species Sept. 4. Vasey grass, nut grass and dewberry resistant. Bermuda grass intermediate. Heavy infestation Florida pusley during late summer. Some upright spurge.
(Telvar W	20 lb					
Simazine	20 lb					
TCA	80 lb					
Inert	80 lb)					
DWK 5815		90	70	50	40	Test 1—Nut grass resistant. Crabgrass infested area during late summer. Test 2—Nut grass and Bermuda grass predominant species Sept. 4. Nut grass resistant. Johnson grass resistant to intermediate. Bermuda grass intermediate. Crabgrass reinfested area during late summer. Test 3—Florida pusley predominant species, maiden cane resistant. Bermuda grass intermediate. Heavy regrowth Florida pusley during late summer.
(Telvar W	40 lb					
Borate	360 lb)					
DWK 5816		98	90	85	40	Test 1—Bermuda grass sprigs and nut grass intermediate. Test 2—Nut grass predominant species Sept. 4. Nut grass and vasey grass resistant. Bermuda grass intermediate. Sandbur infested area during late summer. Test 3—Florida pusley predominant species Sept. 4. Vasey grass resistant but minor. Bermuda grass intermediate. Heavy regrowth Florida pusley.
(Telvar W—TCA	88 lb					
Inert	312 lb)					

Table 4B—Results of Chemical Treatments Applied on Test Areas in Region 4

Type of Vegetation—Predominant species—Crabgrass, nut grass, natal grass, Bermuda grass, upright spurge. Other species—Sandbur, Spanish needle, marestail three seeded mercury, Florida pusley, false golden aster, spiderling, goose grass, lantana, begger's-tick, sheep sorrel, Rhodes grass, windmill grass, vasey grass, Johnson grass, foxtail, signal grass, brambles and saw briers.
Type of Ballast—Granite with limestone sub-ballast—some sandy soil.
Date of Application—March 20–21, 1958.
Weather Data—1958—Avg. Max. Temp.—Jan.—62.5°, Feb.—63.2°, March—73.2°, April—81.8°, May—85.4°, June—92.0°, July—91.9°, Aug.—91.8°, Sept.—91.5°. Precipitation—1957 Annual—50.93". 1958—Jan.—4.49", Feb.—2.83", March—6.16", April—3.79". May—2.68", June—3.83", July—9.93", Aug.—3.40", Sept.—1.65".
Date Inspected—September 5, 1958.

Treatment	*Rate Applied Per Acre*	*Size of Test Plots*	*Percent Control Sept. 5*	*Remarks*
Reade's M/W-4 [1]	435 lb	43 ft x 233 ft	65	Crabgrass, natal grass and upright spurge predominant species Sept. 5. Nut grass and natal grass resistant. Bermuda grass intermediate. Crabgrass, upright spurge, three seeded mercury, Florida pusley, sandbur, marestail infested area after June. Note: Heavy regrowth crabgrass in areas adjacent to asphalt streets indicates leaching of chemical with excess water or run-off from the street.
Reade's M/W-8 [2]	435 lb	43 ft x 582 ft	80	Crabgrass and natal grass predominant species Sept. 5. False golden aster resistant Bermuda grass intermediate. Crabgrass, upright spurge, sandbur, Florida pusley, poppy Spanish needle and spiderling infested area after July 20.
Chlorea Granular [3]	435 lb	65 ft x 250 ft	75	Nut grass and crabgrass predominant species Sept. 5. Nut grass, natal grass, New Jersey tea, and lantana resistant. Crabgrass, sandbur, begger's-tick, three seeded mercury, upright spurge and Florida pusley infested area after July 20. More regrowth on sandy soil ballast than on granite with limestone sub-ballast.
Chlorea Granular	870 lb	63 ft x 150 ft	90	Nut grass and upright spurge predominant species Sept. 5. Nut grass and lantana resistant Bermuda grass intermediate. Upright spurge, crabgrass, sandbur and Florida pusley reinfesting area.
DWK-5813 [4]	200 lb	28 ft x 555 ft	50	Nut grass and crabgrass predominant species Sept. 5. Initial results effective. Nut grass, vasey grass, natal grass and false golden aster resistant. Bermuda grass intermediate Annual species reinfested area after July. These were crabgrass, sandbur, upright spurge three seeded mercury, Spanish needle, Florida pusley, foxtail, Rhodes grass and windmil grass.
DWK-5812 [5]	200 lb	28 ft x 555 ft	40	Bermuda grass, nut grass and natal grass predominant species Sept. 5. Bermuda grass, nut grass, false golden aster, lantana and natal grass resistant. Annual species such as upright spurge, sheep sorrel, sandbur, crabgrass, three seeded mercury, foxtail, Spanish needle and Florida pusley reinfested area after July 20.

TABLE 4B (Continued)

Treatment	*Rate Applied Per Acre*	*Size of Test Plots*	*Percent Control Sept. 5*	*Remarks*
Ureabor[6]	870 lb	39 ft x 442 ft	90	Nut grass, predominant species Sept. 5. Nut grass, vasey grass and lantana resistant. Bermuda grass intermediate. Few plants of Florida pusley, upright spurge, three seeded mercury, crabgrass, and velvet crabgrass.
Nalco 11-174[7]	400 lb	55 ft x 1,126 ft	90	Nut grass predominant species Sept. 5. Nut grass and smilax or sawbriers resistant. Bermuda grass intermediate to susceptible. Brambles intermediate. Few plants of upright spurge, Florida pusley, sandbur, signal grass, crabgrass, foxtail, and lantana present in test area.

[1]Reade's M/W-4—Sodium tetraborate decahydrate 30.8%; sodium pentaborate pentahydrate 63.2%; 3-(p-chlorophenyl)-1,1-dimethylurea 4%.
[2]Reade's M/W-8—Sodium tetraborate decahydrate 87%; 3-(p-chlorophenyl)-1,1-dimethylurea 8%.
[3]Chlorea Granular—Sodium chlorate 40%; sodium metaborate 54%; 3-(p-chlorophenyl)-1,1-dimethylurea 2.4% (Technical).
[4]DWK-5813—Simazine—2-chloro-4, 6-bis-(ethylamino)-s-triazine 10%; TCA-Trichloroacetate 50%; Inert 40%.
[5]DWK-5812—Monuron—3-(p-chlorophenyl)-1,1-dimethylurea 10%; TCA-Trichloroacetate 50%; Inert 40%.
[6]Ureabor—Disodium tetraborate pentahydrate 63.2%; disodium tetraborate decahydrate 30.8%; 3-(p-chlorophenyl)-1,1-dimethylurea 1%.
[7]Nalco 11-174—Sodium tetraborate 83%; 3-(p-chlorophenyl)-1,1-dimethylurea 8%.

Table 5—Cooperative Weed Control Test in Region 5

Application Dates:
Original Application—June 11-24, 1956
Re-treated—June 9-25, 1957
Re-treated—June 2-12, 1958

Inspection Dates:
August 20-23, 1956
May 14-16, 1957
September 10-12, 1957
October 1-2, 1958

Vegetation: Predominant species—smooth brome grass, blue grass and quackgrass.
Other species—smartweed, milkweed, horsetail, willow, buckbrush, knotweed, foxtail grass and Mexican fireweed.

Weather: For Test No's 1, 2 and 3—Avg. Max. Temp: 1957—Jan.—10.8°, Feb.—20°, March—35.8°, Apr.—52.7°, May—69.5°, June—73°, July—86.6°, Aug.—79.5°, Sept.—64.5° Oct.—54.0°, Nov.—33.6°, Dec.—28.3°. 1958—Jan.—25.3°, Feb.—21.6°, March—40.0° Apr.—57.3°, May—72.7°, June— , July—78.1°, Aug.—81.1°, Sept.—71.7°.
Precipitation: 1957—Jan.—.30″, Feb.—.51″, March—.13″, Apr.—.98″, May—3.21″, June—3.78″, July—2.20″, Aug.—4.04″, Sept.—7.54″, Oct.—1.94″, Nov.—0.93″, Dec.—0.11″. Annual—1957—25.67″ (5.62″ above normal). 1958—Jan.—0.09″, Feb.—0.19″, March—0.18″, Apr.—0.75″, May—1.31″, June— , July—5.09″, Aug.—1.32″, Sept.—1.24″.
For Test No's 4, 5 and 6—Avg. Max. Temp: 1957—Jan.—10°, Feb.—18.9° March—33.5° Apr.—49.9°, May—66.1°, June—70.7°, July—85.7°, Aug.—76.4°, Sept.—64.4°, Oct.—52.6°, Nov.—33.9°, Dec.—27.4°. 1958—Jan.—23.2°, Feb.—17.3°, March—36.3°, Apr.—54.8°, May—70.2°, June— , July—76.3°, Aug.—79.8°, Sept.—69.3°.
Preceipitation: 1957—Jan.—.40″, Feb.—.42″, March—.43″, Apr.—.74″, May—1.26″, June—4.14″, July—1.51″, Aug.—4.71″, Sept.—2.26″, Oct.—1.56″, Nov.—0.52″, Dec.—0.29″. Annual—1957—18.24″ (0.62″ above normal). 1958—Jan.—0.37″, Feb.—0.34″, March—0.18″, Apr.—0.66″, May—1.02″, June— , July—3.07″, Aug.—0.80″, Sept.—0.81″.
For Test No's 7, 8, 9 and 10—Avg. Max. Temp: 1957—Jan.—13°, Feb.—21.8°, March—37.8°, Apr.—53°, May—71°, June—74.6°, July—90.2°, Aug.—80.7°, Sept.—70.5°, Oct.—55.9°, Nov.—37.0°, Dec.—31.1°. 1958—Jan.—26.2°, Feb.—20.6°, March—34.8°, Apr.—59.7°, May—75.2°, June— , July—79.6°, Aug.—83.4°, Sept.—72.3°.
Precipitation: 1957—Jan.—.14″, Feb.—.12″, March—.22″, Apr.—.60″, May—.95″, June—4.50″, July—1.01″, Aug.—2.23″, Sept.—0.35″, Oct.—1.54″, Nov.—0.31″, Dec.—0.12″. Annual—1957—12.09″. 1958—Jan.—0.25″, Feb.—0.91″, March—0.16″, Apr.—0.22″, May—0.74″, June— , July—3.92″, Aug.—1.68″, Sept.—0.70″.

Test No.	*Treatment*	*Rate Applied Per Acre*	*Miles Treated*	*Results*
1	Radapon (dalapon)-Methoxone (MCP)	32.5 lb–1.63 lb 36.29 lb–1.81 lb 39.07 lb–1.95 lb 58.68 lb–2.93 lb	12.0 26.5 67.12 22.65	Very good during 1956 season.
	Re-treated 1957 with Radapon 2,4-D	40 lb 6 lb		Results fair to good May 14, 1957. Initial control following re-treatment fair. Considerable regrowth occurred on this line by Sept., 1957. Species reinfesting this area were Mexican fireweed, knotweed, horsetail, foxtail and prostrate spurge. Some blue grass and brome grass surviving.
	Re-treated 1958 with MCP-Chlorea 48 [1]	51.79 gal conc.		Very good to excellent control on Oct. 1, 1958 (85% to 90% control). Some areas spotty with brome grass, blue grass and dandelion.
2	Radapon (dalapon)-Methoxone-Chlorax No. 2	20.64 lb–93.35 gal 21.24 lb–95.59 gal 19.44 lb–87.52 gal 17.18 lb–77.34 gal	31.0 4.0 33.16 20.36	Excellent during 1956 season.
	Re-treated 1957 with Methoxone-Chlorea 800	185 gal		Good control on May 14, 1957. Results Sept., 1957 very good to excellent. Spots of blue grass surviving but chlorotic. Absence of annuals on this line.
	Not treated 1958.			Very good control on Oct. 1, 1958. Some brome grass encroaching along edge.

TABLE 5 (Continued)

Test No.	*Treatment*	*Rate Applied Per Acre*	*Miles Treated*	*Results*
3	Radapon-Methoxone Liquid+ monuron (Telvar W)	7.46–1.50–9.50 lb* 9.66–1.93–7.78 lb* 10.88–2.17–6.73 lb*	25.87 18.13 28.37	Very good during 1956 season.
	Re-treated 1957 with Methoxone-Chlorea 800	195 gal		Very good control on May 14, 1957. Control Sept., 1957, excellent. No appreciable regrowth.
	Not treated 1958.			Very good to excellent control on Oct. 1, 1958 (85% to 90% control). Brome grass encroaching along edge.
4	Methoxone-Chlorax No. 3-monuron (Telvar W) (Same as Methoxone-Chlorea No. 3)	200.4 gal–4.80 lb* 187.86 gal–4.50 lb* 219.8 gal–4.90 lb* 282.16 gal–5.46 lb*	24.07 25.93 4.50 11.48	Fair to excellent during 1956 season.
	Re-treated 1957 with S/M Agronyl-R	83 gal		Results very good, May 14, 1957. Control Sept., 1957 good to very good. Some brome grass encroaching along edges of treated area. Few spots of blue grass surviving.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Very good to excellent control on Oct. 1, 1958. Few spots blue grass and rush grass surviving.
5	Methoxone-Chlorea No. 4	210.6 gal–8.85 lb* 193.87 gal 6.65 lb*	23 31.83	Very good to excellent during 1956 season.
	Re-treated 1957 with None			Results excellent, May 14, 1957. Control very good 15 months following treatment. Some encroachment brome grass and blue grass along edge treated area. Scattered plants of foxtail, prostrate spurge and pigweed in some areas.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Very good to excellent control on Oct. 1, 1958.
6	Chlorax (Chlorate)-TCA No. 2 (TCA)	98.1 lb–17.66 lb 113.5 lb–20.43 lb	27.34 14.60	Fair during 1956 season.
	Re-treated 1957 with S/M Agronyl-R	90 gal		Control fair May 14, 1957. Considerable regrowth with blue grass and brome grass when inspected during Sept., 1957. Apparently this treatment provided control for only a short period in 1957.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Very good control on Oct. 1, 1958.
7	Radapon-Methoxone Liquid	38.29 lb–1.91 lb	28.58	Very good during 1956 season.
	Re-treated 1957 with S M Agronyl-R	88 gal		Results fair to good on May 14, 1957. Re-treatment maintained good control for approximately 6 weeks. Area was reinfested with brome grass, blue grass, Mexican fireweed, foxtail, knotweed, Russian thistle and pigweed when inspected Sept. 12, 1957.
	Re-treated Aug. 1958 with MCP-Chlorax No. 2	90 gal conc.		Very little vegetation on this line early June but heavy growth fireweed by early August. This treatment made during August. Top kill very good Oct. 2, 1958.

TABLE 5 (Continued)

Test No.	*Treatment*	*Rate Applied Per Acre*	*Miles Treated*	*Results*
8	Gamet (Amino Triazole and Methoxone)	7.0 lb–14.0 lb 6.73 lb–13.58 lb 7.2 lb–14.35 lb	23.25 4.75 21.24	Fair during 1956 season.
	Re-treated 1957 with S/M Agronyl-R	88 gal		Control fair May 15, 1957. Some evidence of initial top burn but grasses had recovered by Sept. 11, 1957. Some annuals such as fireweed and foxtail infested area following treatment.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Very good control on Oct. 2, 1958. Some brome grass and blue grass surviving in spots.
9	TCA (4)-Chlorax No. 2 (Chlorate)	66.46 lb–23.93 lb 75.53 lb–27.19 lb	22.14 23.32	Poor during 1956 season.
	Re-treated 1957 with S/M Agronyl-R	81 gal		Results poor May 15, 1957. Grasses predominant on this line. Heavy growth blue grass and brome grass when inspected Sept. 11, 1957.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Very good control. Oct. 2, 1958.
10	Ammate emulsion (Ammate X)+monuron (Telvar W) +476 gal oil slurry	32.16 lb–5.58 lb 24.75 lb–6.04 lb 27.69 lb–8.4 lb	24.27 11.00 25.29	Good during 1956 season.
	Re-treated 1957 with S/M Agronyl-R	81 gal		Results fair to good, May 15, 1957. General control on this line considered good when inspected Sept. 15, 1957. Difficulties encountered during original treatment in injecting monuron-oil slurry in Ammate emulsion resulting in small scattered areas not treated with monuron. Considerable regrowth occurred in these areas. Results very good where monuron was included in treatment.
	Re-treated 1958 with MCP-Chlorea 48	51.79 gal conc.		Good to excellent control on Oct. 1, 1958. Some areas excellent. Other areas with brome grass surviving.

*Lb of Telvar W (CMU—80%).
[1]MCP-Chlorea—Equivalent to 2.07 lb MCP per acre, 90.6 lb sodium chlorate per acre, 51.8 lb sodium metaborate per acre, 8.18 Telvar W per acre.

Table 6—Results of Chemical Treatments Applied on Test Areas in Region 6

Type of Vegetation—Predominant species—Indiangrass, Johnson grass, big bluestem, little bluestem, sunflower, leavenworth eryngo, Bermuda grass, silver bluestem, ragweed, tall dropseed.
Other species—Purple nightshade, sideoats grama, aster, broomsedge bluestem, sandbur, prairie threeawn, buffalo-bur, Carolina horsenettle, woolly verbena, daisy fleabane, cocklebur, Mexican fireweed, Russian thistle, prostrate spurge, upright spurge, smilax spp. and lovegrass.
Type of Ballast—Gravel.
Date of Application—Test No's 1 through 4—Nov. 2, 1957; Test No. 5—Nov. 10, 1957; Test No. 6—Oct. 31, 1957.
Width of Treatment—24 ft.
Weather Data—Test No's 1 through 5—Precipitation—1957—Oct.—5.00", Nov.—4.56", Dec.—2.98". Annual—1957—50.43". 1958—Jan.—2.16", Feb.—0.68", March—2.55", Apr.—5.03", May—4.38", June—0.47", July—4.76", Aug.—1.38", Sept.—7.13".
Test No. 6—Avg. Temperature—1957—Oct.—63.2°, Nov.—53.4°, Dec.—52.9°, Annual 1957—66.3°. 1958—Jan.—47.0°, Feb.—45.6°, March—51.1°, Apr.—63.5°, May—73.6°, June—94.3°, July—96.6°, Aug.—97.7°, Sept.—86.9°. Precipitation—1957—Oct.—7.21", Nov.—5.89", Dec.—2.14", Annual—1957—50.95" (16.63" above normal). 1958—Jan.—2.15", Feb.—1.29", March—3.46", Apr.—5.87", May—3.18", June—2.35", July—3.13", Aug.—5.20", Sept.—6.71".
Date Inspected—May 13–14, 1958 and Sept. 23–24, 1958.

Test No.	*Treatment*	*Rate Applied Per Acre*	*Size of Test Area*	*Average Percent Control*				*Remarks*
				May 13–14		*Sept. 23–24*		
				O.G.[1]	*I.G.*[2]	*O.G.*	*I.G.*	
1	Sodium chlorate Sodium metaborate Telvar W	56.22 lb 133.05 lb 4.31 lb	6.9 mi	31.64	42.45	20.51	0	This treatment appears inadequate for controlling vegetation in this area under the high rainfall conditions that occurred since application. Annual species were killed and replaced by other annuals. Johnson grass was injured but was regrowing. Predominant species in Sept. 1958 were Johnson grass, upright spurge, sunflower and prostrate spurge. Resistant species were Johnson grass, Indiangrass, big blue stem, horsenettle, Bermuda grass, silver blue stem and little blue stem. Annuals reinfested gage but their density rating was approximately 30 percent.
2	Sodium chlorate Sodium metaborate Telvar W	57.90 lb 127.02 lb 6.65 lb	6.7 mi	27.91	28.92	20.30	0	Predominant species Sept. 1958 Johnson grass and Indiangrass. Resistant species were Johnson grass, Bermuda grass, Indiangrass, silver blue stem, little blue stem and false golden aster. Annuals reinfesting area were upright spurge, Russian thistle and ragweed. Horsenettle was growing vigorously in May but its density had been greatly reduced in Sept. The gage contained very little vegetation at time of treatment. It was reinfested primarily with annuals, the density of which was 20%. This treatment was inadequate.
3	Sodium chlorate Sodium metaborate Telvar W	55.98 lb 132.50 lb 8.58 lb	6.9 mi	33.35	37.02	28.89	0	Predominant species Sept. 1958 Johnson grass, Bermuda grass, annuals and smilax spp. Resistant species were Johnson grass, silver blue stem, Indiangrass, Bermuda grass, smilax spp. and purple nightshade. Horsenettle was intermediate. Upright spurge reinfested area. The gage contained very little vegetation at time of treatment. It was reinfested primarily with annuals.

TABLE 6 (Continued)

Test No.	Treatment	Rate Applied Per Acre	Size of Test Area	Average Percent Control				Remarks
				May 13–14		Sept. 23–24		
				O.G.[1]	I.G.[2]	O.G.	I.G.	
4	Sodium chlorate Sodium metaborate Telvar W	57.90 lb 137.03 lb 11.09 lb	6.7 mi	31.28	42.44	37.13	20.01	Predominant species Sept. 1958 Johnson grass, silver bluestem and Bermuda grass. Resistant species were Johnson grass, silver bluestem, Indiangrass, purple nightshade, Bermuda grass and little bluestem. Horsenettle intermediate. Upright spurge reinfesting area. Growth of some perennials retarded. Some annuals eliminated but others regrowing.
5	Sodium chlorate Sodium metaborate Telvar W	105.57 lb 249.88 lb 9.05 lb	4.8 mi	54.41	57.29	64.12	1.30	This treatment provided fairly good control of most vegetation. Johnson grass stand had been reduced considerably but some plants were surviving. Indiangrass, big blue stem and little blue stem were resistant. Some upright spurge, prostrate spurge and three seeded mercury were reinfesting the area primarily between the gage. Vine-misquite and purple nightshade were surviving.
6	Chlorea Granular[3]	400 lb	0.6 mi	36.89	66.13	12.72	38.38	Predominant species Sept. 1958 Johnson grass and Bermuda grass. Resistant species Johnson grass, Bermuda grass and purple nightshade. Annual species eliminated but area was heavily reinfested with Johnson grass and Bermuda grass. This treatment was ineffective at this rate under the high rainfall conditions found in this region since the material was applied.

[1]O-G—Outside gage.
[2]I-G—Inside gage.
[3]Chlorea Granular—Sodium chlorate 40%; sodium metaborate 54%; 3-(p-chlorophenyl)-1,1-dimethylurea 2.4% (Technical).

TABLE 7—RESULTS OF BRUSH CONTROL TESTS REGIONS 1, 2 AND 6

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Date Inspected*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
REGION 1							
Ammate X [1]	180 lb in 300 gal water	July, 1958	Aug. 20, 1958	Avg. Max. Temp.: 1958—Jan.—29.0°, Feb.—24.1°, Mar.—40.8°, Apr.—58.6°, May—72.6°, June—73.4°, July—80.0°, Aug.—81.3°, Sept.—72.8°. Precipitation—Annual 1957—45.5″; 1958—Jan.—0.21″, Feb.—0.24″, Mar.—0.32″, Apr.—1.99″, May—1.39″, June—2.01″, July—3.15″, Aug.—3.03″, Sept.—1.09″.	Sumac, elm and oak	90	Percent control based on top kill. Too early to determine stem and root kill.
2,4-D—2,4,5-T [2]	1 gal	July, 1958	Aug. 20, 1958	"	"	90	"
Trysben 200 [3]	4 lb	July, 1958	Aug. 20, 1958	"	"	98	"
TBA-Granules [4]	60 lb	July, 1958	Aug. 20, 1958	"	"	Symptoms only	Leaves on all species beginning to show symptoms of being injured by the chemical. Too early to determine effectiveness of this material.
Fenuron pellets [5]	60 lb	July, 1958	Aug. 20, 1958	"	"	Symptoms only	Leaves chlorotic. Showing signs of serious injury but too early to determine the effectiveness of this material.
REGION 2							
Fenuron pellets	16 lb	June 19, 1958	Aug. 12, 1958	Avg. Max. Temp.: 1958—Jan.—31.5°, Feb.—26.7°, Mar.—41.0°, Apr.—60.4°, May—73.1°, June—74.1°, July—81.5°, Aug.—83.2°, Sept.—75.5°. Precipitation—1957—Annual 44.29″; 1958—Jan.—1.12″, Feb. 0.33″, Mar.—0.33″, Apr.—1.64″, May—3.12″, June—6.43″, July—4.74″, Aug.—2.51″, Sept.—1.86″.	Willow	5	Leaves beginning to show chlorosis. Too early to determine effects at this low rate.

TABLE 7 (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Date Inspected*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
Fenuron pellets	32 lb	June 19, 1958	Aug. 12, 1958	"	"	5	Leaves beginning to show signs of chlorosis.
Fenuron pellets	64 lb	June 19, 1958	Aug. 12, 1958	"	"	20	Leaves chlorotic indicating serious injury.
TBA Granules	16 lb	June 25, 1958	Aug. 12, 1958	"	"	10	Leaves beginning to show signs of injury.
TBA Granules	48 lb	June 25, 1958	Aug. 12, 1958	"	"	50	Willow bushes seriously injured and appear to be dying.
TBA Granules	64 lb	June 25, 1958	Aug. 12, 1958	"	"	90	Good kill.
REGION 6							
Fenuron pellets	36 lb	May 22, 1958	Sept. 25, 1958	Avg. Max. Temp.: 1958—Jan.—59.3°, Feb.—57.8°, Mar.—65.8°, Apr.—78.5°, May—88.1°, June—95.9°, July—98.1°, Aug.—97.9°, Sept.—89.0°. Precipitation—1957 Annual—56.10"; 1958—Jan.—3.05", Feb.—2.72", Mar.—1.58", Apr.—4.17", May—1.99", June—2.40", July—7.06", Aug.—1.66", Sept.—12.13".	Post oak, blackjack oak, chitamwood, grape, dewberry, trumpet vine.	15	Aerial application. Leaves browning around edge and showing symptoms of injury. Too early to determine effectiveness of treatment.
Fenuron pellets	48 lb	May 22, 1958	Sept. 25, 1958	"	"	55	Aerial application. Some defoliation. All species injured and appeared to be dying.
TBA Granules	26 lb	May 22, 1958	Sept. 25, 1958	"	"	----------	Aerial application. Brush injured.
TBA Granules	40 lb	May 22, 1958	Sept. 25, 1958	"	"	30	Aerial application. Some defoliation. Leaves turning brown and showing signs of injury.

TABLE 7 (Continued)

Treatment	*Rate Applied Per Acre*	*Date Applied*	*Date Inspected*	*Weather*	*Type of Vegetation*	*Percent Control*	*Remarks*
TBA Granules[4] Fenuron pellets[5]	13 lb 24 lb	May 22, 1958	Sept. 25, 1958	"	"	40	Aerial application. Some defoliation. Grape vines killed. Oak leaves turning brown showing signs of severe injury.
Nalco H-174 Granules[6]	80 lb	May 22, 1958	Sept. 25, 1958	"	"	30	Aerial application. Leaves turning brown around edge. Too early to determine effectiveness.

[1]Ammate X—Ammonium sulfamate 95%.
[2]2,4-D—2,4,5-T—2,4-Dichlorophenoxyacetic acid 2 lb acid equivalent per gal; 2,4,5-Trichlorophenoxyacetic acid 2 lb acid equivalent per gal.
[3]Trysben 200—Dimethylamine salt of Trichlorobenzoic acid 24.8%; dimethylamine salt of other Polychlorobenzoic acid 1.3%; total active ingredient 26.1%; 2 lb trichlorobenzoic acid equivalent per gal.
[4]TBA—Granules (Trysben Granules)—Trichlorobenzoic acid 25%.
[5]Fenuron pellets—3-phenyl-1,1-dimethylurea 25%.
[6]Nalco H-174 Granules—Sodium metaborate, 3-(p-chlorophenyl)-1,1-dimethylurea, 8.1% active ingredient.

TABLE 8—COST OF MATERIALS USED FOR VEGETATION CONTROL DURING 1958 (FOB PLANT)

Chemical	*Composition*	*Recommended Rate Per Acre*	*Dilution of Concentrate Chemical:Water*	*Cost Per Lb or Gal*	*Cost Per Acre*
1. Agronyl R	Aromatic oil	80–120 gal	None	$0.095	$7.60–11.40
2. Atlacide Liquid	Calcium chlorate 25%, sodium chloride 14%, inert ingredient 61%	50–80 gal	1:3	$0.49	$24.50–39.20
3. Atlacide-2,4-D S.P.	Sodium chlorate 58%, 2,4-Dichlorophenoxyacetic acid .1% (acid equiv.)	600–800 lb	Dry	$0.1025	$61.50–82.00
4. Atlas A	Arsenic trioxide (As_2O_3) 4 lb per gal conc.	20–100 gal	1:7–1:9	$0.345	$6.90–34.50
5. Atlas D	Arsenic trioxide (As_2O_3) 3.77 lb per gal conc.+ animal repellent	20–100 gal	1:6–1:9	$0.495	$9.90–49.50
6. Baron	2-(2,4,5-trichlorophenoxy) ethyl 2,2 dichloropropionate, 4 lb per gal	5–40 gal conc	1:8	$4.40	$22.00–176.00
7. Borascu 46	46% B_2O_3	4,000–6,000 lb	Dry	$0.02075	$83.00–124.50
8. Calabor No. 33 Weed Killer	Ammate X 0.25 lb/gal, dalapon 0.3 lb/gal	90–100 gal conc	1:1	$0.32	$28.80–32.00
9. Calabor No. 42 Weed Killer	Sodium chlorate 1.8 lb/gal, sodium metaborate 1.15 lb/gal and surfactants	60–66 gal conc	1:1 to 1:3	$0.285–0.32/gal	$17.10–21.12
10. Chlorate-Chloride	Sodium chlorate 3 lb per gal, calcium chloride 2¼ lb per gal	50–60 gal conc	1:4	$0.48/gal	$24.00–28.00
11. Chlorax Liquid	Sodium chlorate 18.2%, sodium metaborate* 10%, inert ingredient 71.8% *Equivalent to 1.67% boron as expressed as element boron.	80–100 gal	1:1 or 1:2 or 1:3	$0.385	$30.80–38.50
12. Chlorax "40" S.P.	Sodium chlorate 40%, sodium metaborate 57%	435–800 lb	Dry	$0.12	$52.20–96.00
13. Chlorea Granular No. 3	Sodium chlorate 40%, sodium metaborate 54%, (CMU)-3-(p-chlorophenyl)-1,1-dimethylurea 2.4% (Technical)	300–600 lb	Dry	$0.26 CL	$78.00–156.00
14. Chlorea Liquid 14	Sodium chlorate 18.2%, sodium metaborate 10%, Telvar W 0.85%	50 gal	1:1 or 1:2 or 1:3	$0.63	$31.50
15. Chlorea Liquid 16	Sodium chlorate 18.2%, sodium metaborate 10%, Telvar W 1.3%	50 gal	1:1 or 1:2 or 1:3	$0.75	$37.50
16. Chlorea Liquid 18	Sodium chlorate 18.2%, sodium metaborate 10%, Telvar W 1.7%	50 gal	1:1 or 1:2 or 1:3	$0.87	$43.50

TABLE 8 (Continued)

Chemical	*Composition*	*Recommended Rate Per Acre*	*Dilution of Concentrate Chemical:Water*	*Cost Per Lb or Gal*	*Cost Per Acre*
17. Concentrated Borascu	65% B_2O_3	2,610–4,356 lb	Dry	$0.0345	$90.05–150.07
18. Conoco Weed Spray Oil	Gravity, API 13; Flash, P.M. 220; Vis. at 100, SSU 42; Pour Point, °F. plus 15; Sulphur, % 1.1; Aromatics, %, D1019–51, 60; Color, Opaque. Distillation: I.B.P. 436; Recovered 10% 490°; 20% 512°; 50% 574°; 90% 670°, End Point 750°	75 gal	None	$0.10	$7.50
19. 2,4-Dow Weed Killer Formula 40	Alkanolamine salts of 2,4-Dichlorophenoxyacetic acid 4 lb acid equiv/gal	1–2 gal	1:100	$2.62	$2.62–5.24
20. Esteron Ten-Ten	Propylene glycol butyl ether ester of 2,4-Dichlorophenoxyacetic acid 4 lb acid equiv/gal	1–2 gal	1:100	$3.92	$3.92–7.84
21. Garlon	Contains diethylene glycol bis 2,2 dichloropropionate and 2-(2,4,5-trichlorophenoxy) propionic acid Propylene glycol butyl ether esters	5–8 gal/acre in 150-300 gal water		$5.75/gal	$28.75–46.00
22. Granicide "A"	Sodium chlorate 14.50%, sodium perborate 3.00%, sodium sulfate 2.20%, 2,4-Dichlorophenoxyacetic acid 0.50%, active ingredient 20.20%, inert ingredient 79.80%	82.5 gal	1:3	$0.39	$32.18
23. Granicide 2X	Sodium chlorate 14.50%, sodium perborate 3.00%, sodium sulfate 2.20%, ammonium sulfamate 2.00%, active ingredient 21.70%, inert ingredient 78.30%	82.5 gal	1:3	$0.405	$33.41
24. 20% HCA Oil Solution	Hexachloroacetone 20% 1 part, oil 9 parts	100–150 gal	None	$0.35	$35.00–52.50
25. HCA, Oil and 2,4-D 2% Soln.	Hexachloroacetone 20% 10 gal, 2,4-D 1 gal, oil 89 gal	100–150 gal	None	$0.40	$40.00–60.00
26. Herbicide (1¼ Caustic)	As_2O_3 4 lb per gal, NaOH 1¼ lb per gal	82.5 gal	1:3	$0.41	$33.83
27. Herbicide-NP	Sodium chlorate 3 lb per gal, calcium chloride 2.25 lb per gal	82.5 gal	1:3	$0.56	$46.20
28. Herbicidol Regular [1]	As_2O_3 13.00%, oil 51.80%, cresols 2.30%, xylenols 1.50%, phenols 0.60%, 2,4-Dichlorophenoxyacetic acid 0.50%, emulsifying, activating and penetrating agents 15.00%, active ingredient 84.70%, inert ingredient 15.30%	82.5 gal	1:3	$0.445	$36.71

TABLE 8 (Continued)

Chemical	*Composition*	*Recommended Rate Per Acre*	*Dilution of Concentrate Chemical:Water*	*Cost Per Lb or Gal*	*Cost Per Acre*
29. Herbicidol-NP Regular[2]	Oil 21.40%, cresols 1.80%, xylenols 1.20%, phenols 0.50%, sodium trichloroacetate 7.00%, 2,4-Dichlorophenoxyacetic acid 1.10%, emulsifying, penetrating, binding and activating agents 12.00%, total active ingredient 45.00%, inert ingredient 55.00%	82.5 gal	1:3	$0.505	$41.66
30. Hykil-HCA Weed Killer	Aromatic oil+surfactants+2% hexachloroacetone by volume	75–100 gal	2 HCA:98 oil	$0.265–0.295	$19.88–29.50
31. Hykil-Monuron	Aromatic oil+surfactants with monuron	80 gal oil+ 8 lb monuron	1:1 oil with water		$27.60
32. Hykil Weed Killer No. 60	Aromatic oil and surfactants. Slightly varied specifications from various plants similar to previous.	75–100 gal	None or 1:1 water with oil	$0.095/gal	$7.13–9.50
33. "Karmex" Diuron Weed Killer	Diuron-3-(3,4-dichlorophenyl)-1,1-dimethylurea—80%	10–40 lb	up to .5 per gal	$3.30	$33.00–132.00
34. Methoxone-Chlorax Conc.	Sodium chlorate 16.3%, sodium metaborate 9.1%, 2-methyl-4-chlorophenoxyacetic acid .2%, inert ingredient +74.4%	80–100 gal	1:1	$0.393	$31.44–39.30
35. Methoxone-Chlorea 14	Sodium chlorate 16.3%, sodium metaborate 9.1%, MCP acid 0.4%, Telvar W 0.8%	50 gal	1:1 or 1:2 or 1:3	$0.639	$31.95
36. Methoxone-Chlorea 16	Sodium chlorate 16.3%, sodium metaborate 9.1%, MCP acid 0.4%, Telvar W 1.2%	50 gal	1:1 or 1:2 or 1:3	$0.759	$37.95
37. Methoxone-Chlorea 18	Sodium chlorate 16.3%, sodium metaborate 9.1%, MCP acid 0.4%, Telvar W 1.6%	50 gal	1:1 or 1:2 or 1:3	$0.879	$43.95
38. Monobor-Chlorate No. 2	Sodium borate 10%, sodium chlorate 7%	100–200 gal		$0.155–0.175	$15.50–35.00
39. Nalco H-174	3-(p-chlorophenyl)-1,1-dimethylurea—8.0%, sodium tetraborate—83%, inert (surfactants)—9.0%	200–400 lb	Dry	$0.48/lb	$96.00–192.00
40. Nalco H-170	Aromatic petroleum oil—98%, pentachlorophenol—0.87%, 2,4-D iso-octyl ester—1.13%, (2,4-D acid equivalent—0.72%)	44 gal	None	$0.383/gal	$16.85
41. Nalco H-178D	Aromatic petroleum oil+surfactants—95.00%, pentachlorophenol—5.00%	20 gal	1:10	$0.52/gal	$10.40

TABLE 8 (Continued)

Chemical	*Composition*	*Recommended Rate Per Acre*	*Dilution of Concentrate Chemical:Water*	*Cost Per Lb or Gal*	*Cost Per Acre*
42. Polybor Chlorate	Disodium octaborate 73%, sodium chlorate 25%, boron trioxide content 49%	800–1,600 lb	Dry or 2 lb/gal of water	$0.0865	$69.20–138.40
43. Radapon (Liquid)	2,2 dichloropropionic acid, 4 lb per gal 78% dalapon sodium salt	20–40 lb or 5–10 gal	1:32	$2.72–2.96/gal	$13.60–29.60
44. Radapon-2,4-D	2,2 dichloropropionic acid, 2,4-Dichlorophenoxy acetic acid, amine salt	10–14 gal conc 2 gal conc	1:10 1:100		$33.00–43.00
45. Reade M/W-4 Dry Weed Killer	Sodium tetraborate decahydrate ($Na_2B_4O_7.10H_2O$) 30.8%, sodium tetraborate pentahydrate ($Na_2B_4O_7.5H_2O$) 63.2%, 3-(p-chlorophenyl)-1,1-dimethylurea 4.0%, inert ingredient 2.0%	Annuals 218–435 lb Perennials 435–870 lb	Dry	$0.23–0.28	$50.14–243.60
46. Reade M/W-8 Dry Weed Killer	3-(p-chlorophenyl)-1,1-dimethylurea 8.0%, sodium tetraborate decahydrate ($Na_2B_4O_7.10H_2O$) 87.0%, inert ingredient 5.0%	Annuals 218–435 lb Perennials 435–870 lb	Dry	$0.42–0.47	$91.56–408.90
47. Reade 4X Weed Killer	Cresols 2.90%, xylenols 2.00%, phenols 0.80%, 2,4-Dichlorophenoxyacetic acid 2.30%, 3-(p-chlorophenyl)-1,1-dimethylurea 0.44%, sodium pentachlorophenate 0.27%, emulsifying, activating and penetrating agents 18.00%, active ingredient 26.71%, inert ingredient 73.29%	82.5 gal	1:3	$0.515	$42.49
48. Simazine 50W	2-chloro-4, 6-bis-(ethylamino)-s-triazine	20–40 lb		$2.37/lb	$47.40–94.80
49. Sodium Arsenite	Arsenic trioxide 4 lb per gal, sodium hydroxide 1 lb per gal	50–60 gal conc	1:4	$0.34	$17.00–21.00
50. Sodium TCA Solution	Sodium trichloroacetate 90% 6 lb per gal	7–15 gal	1:15 to 1:30	$1.69–1.93	$11.83–28.95
51. TCA-Chlorate	Sodium trichloroacetate 90% 1.25 lb per gal, sodium chlorate 99% 2.5 lb per gal+additives and dye	36–40 gal	1:4	$0.90/gal	$32.40–36.00
52. TCA-Chlorate (Regular)	Sodium chlorate 2 lb per gal, trichloroacetate 2/3 lb per gal	50–60 gal conc	1:4	$0.48	$24.00–28.00
53. TCA-Chlorate (Special A)	Sodium chlorate 2 lb per gal, trichloroacetate 2/3 lb per gal, calcium chloride 1.2 lb per gal	50–60 gal conc	1:4	$0.52	$26.00–30.00

TABLE 8 (Continued)

Chemical	Composition	Recommended Rate Per Acre	Dilution of Concentrate Chemical:Water	Cost Per Lb or Gal	Cost Per Acre
54. TCA-Chlorate (Special D)	Sodium chlorate 2½ lb per gal, trichloroacetate 1¼ lb per gal, calcium chloride 1½ lb per gal	45–50 gal conc	1:5	$0.76	$35.00–38.00
55. TCA-Chlorax	Sodium chlorate 14.2%, sodium metaborate 7.93%, sodium trichloroacetate 2.61%	80–100 gal	----------	$0.40	$32.00–40.00
56. "Telvar" Monuron Weed Killer	Monuron-3-(p-chlorophenyl)-1,1-dimethylurea—80% active ingredient	10–40 lb	up to .5 per gal	$2.60	$26.00–104.00
57. Trysben 200 Weed Killer	Dimethylamine salt of trichlorobenzoic acid 24.8%, Dimethylamine salt of other polychlorobenzoic acid 1.3%. Total active ingredients 26.1%.	5–10 gal	1 gal/10–20 gal	$10.00/gal	$50.00–100.00
58. Ureabor	Disodium tetraborate pentahydrate 63.2%, disodium tetraborate decahydrate 30.8%, 3-(p-chlorophenyl)-1,1-dimethylurea 4%	400–800 lb	Dry	$0.235	$94.00–188.00
59. Urox 11	3-(p-chlorophenyl)-1,1-dimethylurea trichloroacetate 11%	200–400 lb	None	$0.50–0.55/lb	$100.00–220.00
60. Urox 22	3-(p-chlorophenyl)-1,1-dimethylurea trichloroacetate 22%	125–200 lb	None	$0.75–0.85/lb	$93.75–170.00
	BRUSH				
1. Ammate Weed and Brush killer Solution	Ammonium Sulfamate 95%	32–48 gal	10.7 gal/100 gal	$0.86/gal	$27.52–41.28
2. Brush Killer 22	Iso-octyl ester of the 2,4-Dichlorophenoxyacetic acid 33.7%, Iso-octyl ester of the 2,4,5-Trichlorophenoxyacetic acid 32.1%, inert ingredient 34.2%, total ingredient 100%	1.65–2 gal	1:113–1:150	----------	$14.00–20.00
3. Dybar Fenuron Weed and Brush Killer Pellets	Fenuron (3-phenyl-1,1-dimethylurea) 25% active ingredient	16–75 lb	applied as formulated	$1.00/lb	$16.00–75.00
4. Esteron 245 O.S.	Propylene glycol butyl ether ester 2,4,5-Trichlorophenoxyacetic acid 4 lb acid equiv/gal	2–3 gal conc	1:100–1:125	$7.95–8.54	$15.90–25.62
5. Kuron	Low volatile propylene glycol butyl ether ester, 2-(2,4,5-Trichlorophenoxy) proprionic acid 4 lb acid equiv/gal	2–3 gal conc	1:100–1:125	$8.51–8.6735	$17.02–26.02

TABLE 8 (Continued)

Chemical	*Composition*	*Recommended Rate Per Acre*	*Dilution of Concentrate Chemical:Water*	*Cost Per Lb or Gal*	*Cost Per Acre*
6. Esteron Brush Killer	Propylene glycol butyl ether ester-2,4-Dichlorophenoxyacetic acid 2 lb acid equiv/gal and propylene glycol butyl ether ester-2,4,5-Trichlorophenoxyacetic acid 2 lb acid equiv/gal	2-3 gal conc	1:100-1:125	$5.82-6.30	$11.64-18.90
7. Low Volatile Brush Killer	Acid equivalent 4 lb per gal	*Foliage Spray* 1 gal to 100 to 150 gal water Add .1% by wt. wetting agent *Basal Dormant or Stump* 1 gal in 24 gal diesel oil Wet Foliage	*Foliage Spray* 1:100-1:150 *Basal Dormant or Stump* 1:24 oil	$6.63 LCL	$13.26-19.89
8. Low Volatile Ester 2,4,5-T	Acid equivalent 4 lb per gal	Wet foliage 2-3 gal conc	1:100	$8.60 LTL	$17.20-25.80
9. Trysben 200 Weed Killer[3]	Dimethylamine salt of Trichlorobenzoic acid 24.8%. Dimethylamine salt of other Polychlorobenzoic acid 1.3%. Total active ingredients 26.1%.	2-6 gal	2 gal/100	$10.00 gal	$20.00-60.00
10. Veon Brush Killer	Amine formulation 2,4-Dichlorophenoxyacetic acid 2 lb acid equiv/gal conc, 2,4,5-Trichlorophenoxyacetic acid 2 lb acid equiv/gal	2-3 gal conc	1:100-1:125	$5.82-5.985	$11.64-17.96
11. Veon 245	Amine salt formulation 2,4,5-Trichlorophenoxyacetic acid 4 lb acid equiv per gal	2-3 gal conc	1:100-1:125	$7.95-8.113	$15.90-24.34

[1]Herbicidol Regular also supplied with additives.
[2]Herbicidol-NP Regular also supplied with additives.
[3]Recommended only for controlling conifers, sumac, sassafras and hackberry at the present.

Part 4—Cost of Developing a New Herbicide

With increased use of chemicals for vegetation control and the need for improved materials tremendous advances have been made in the development of new herbicides. In this connection, the question, "What does it cost to develop a new herbicide?" has been asked often during recent years. The following is a review of the present information concerning the expense involved in developing a new herbicide.

There are many factors which influence the cost of discovering and developing a new chemical to be used for vegetation control. Some chemical compounds may present very few problems in their development and may be available for commercial use within a minimum of 4 years. Others may present numerous problems, and it may require a maximum of 10 to 11 years before they can be placed on the market.

The present development and evaulation tests on new herbicides are not only conducted by the chemical industry but the chemicals are often furnished to public agencies and industrial research personnel for their tests. However, most companies have facilities to give them an evaluation before they are forwarded to other groups. According to L. L. Coulter[1], all new herbicide compounds must be subject to basic laboratory tests before becoming candidates for weed control herbicides. Field research dollars cannot justifiably be expended on compounds which have not shown real phytotoxic merits, are too hazardous to use, are uneconomical to produce, or are too difficult to formulate.

J. A. Field and R. H. Wellman[2] state that "to obtain one successful agricultural chemical about 1800 compounds must be synthesized and run through biological screens. On the average, it costs $150 to synthesize a chemical and $200 to run it through biological screens. The initial research cost is then a total of 1800 compounds, in each of which $350 is invested. Only 1 in 30 of these compounds survives the initial screening, and the cost of the failures must be borne by those that continue. A total of $10,500 is, therefore, invested in each of the remaining chemicals. Further laboratory and greenhouse work will cost $1000 each, making a total of $11,500 for each chemical. Only 1 chemical in 10 will merit further consideration. In each of these (adding the cost of failures), $115,500 is invested. Initial field tests will cost at least $1000 per chemical, which must be added to the $115,000. Only 1 in 3 of these compounds will be worth a full-scale development effort. So there remains 2 chemicals, from the 1800 compounds, that have cost so far about $348,000 each. To this must be added $250,000 development cost for each, which is made up of field studies, analytical methods, residue analyses, toxicological studies, production, research and pilot plant construction and cost of securing patents. The total cost of each of the two remaining chemicals is now approximately $600,000. If only one of the two compounds achieves commercial markets, the full price tag will read $1,200,000."

According to Mark G. Wiltse[3], "the cost of a new product will have to include some or all of the expense of discovering and developing a new herbicide similar to those outlined below:

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[1] Coulter, L. L., "Right-of-Way Brush Control Research and It's Ramifications," Proceedings 12th Annual Meeting, NEWCC, New York, January 1958, page 213.

[2] Field, J. A., and Wellman, R. H., "A Teen-Ager Growing Up", National Agricultural Chemicals Association News and Pesticide Review, March-April, 1956, page 4.

[3] Wiltse, Mark G., "Profit and Loss with Aquatic Weeds". Proceedings 12th Annual Meeting, NEWCC, New York, January 1958, page 356.

Item	*Dollars*
Synthesizing and Screening	$ 70,000
Patent Cost	8,000
Field Testing	475,000
Pilot Plant	50,000
Analytical Methods	130,000
Residue and Flavor Studies	335,000
Toxicology Studies	75,000
Formulation, Corrosion and Packaging Studies	125,000
Registration, Legal, Miscellaneous	100,000
Total	$1,368,000

"These figures represent the expense in discovering and developing an average new product."

Charles O. Barnard[4] reported that from a survey of several major producers of pesticide chemicals, the minimum cost was $500,000 for a pesticide chemical that apparently encountered no serious roadblocks on its way to certification of usefulness by USDA, and the establishment of official tolerances by FDA under Public Law 518 (Miller Amendment). Another compound, however, created for its owner a frustrating variety of obstacles to commercial registration, and its development cost rocketed to nearly $3,250,000. He stated that the probable range confronting developers of new pesticide chemicals appears to be $750,000 to $3,250,000, and the trend is constantly upward.

Dr. Max Goebel[5] reported that more than $3,000,000 was invested in discovering and developing the urea herbicides. Well over half of this sum was spent in evaluating and demonstrating the effectiveness of these materials.

The figure generally used in references to developing new herbicides is about $1,000,000. This includes toxicology tests and finding where the chemical fits. In discussion groups this figure ranged from $300,000 to $1,000,000. In one instance, the toxicology tests on a chemical was $750,000.

The work involved in discovering and developing a new herbicide is expensive, time consuming, and is likely to bear fruit only many years after the initiation of such a program. However, it should be mentioned that it is not too difficult to find compounds that have activity. The difficult part is trying to find enough areas where they can be used in competition with other chemicals to make them worthwhile to produce. The chemical companies admit that they run across many compounds that are highly specific for a certain problem, but the potential market is so small that these compounds remain on the shelf.

One important point to remember when considering the development of a herbicide for industrial purposes is that plants vary greatly in their reaction to chemicals. As yet, in the whole soil sterilant or general vegetation control program, we have no compound that will kill all plants unless they are used at excessively high rates. It seems logical that we will not have one in the future because of this difference in plant reaction.

[4] Charles O. Barnard, "Pesticide Development Cost," Journal of Agricultural and Food Chemistry, Volume 6, No. 7, July 1958, page 512.

[5] Goebel, Max, "Weed Control—An Industry Point of View," Proceedings 13th Annual Meeting, NCWCC, Chicago, December 1956, page 2.

Report of Committee 5—Track

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J. B. WILSON
B. J. WORLEY
M. J. ZEEMAN
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revision of Specifications for Soft Steel Cut Track Spikes, submitted for adoption ..... page 786

2. Track tools, collaborating with Purchases and Stores Division, AAR.
   No report. Your committee has asked for an assignment to make a standard design for lag screws and drive screw spikes.

3. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.
   Progress report, with recommendations submitted for adoption and publication in the Portfolio of Track Plans ..... page 787
   Appendix 3–a. Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill. ..... page 792

4. Prevention of damage resulting from brine drippings on track and structures, collaborating with Committee 15, and Mechanical Division, AAR.
   Progress report, submitted as information. Covers further investigation seeking to find non-toxic brine corrosion inhibitors ..... page 793

5. Design of tie plates, collaborating with Committees 3 and 4.
No report. Study is being continued.

6. Hold-down fastenings for tie plates, including pads under plates; their effect on tie wear, collaborating with Committee 3.

Progress report, presented as information, covering the service test installation of hold-down fastenings, tie pads, etc., on the Louisville & Nashville near London and East Bernstadt, Ky. ..... page 800

7. Effect of lubrication in preventing frozen rail joints and retarding corrosion of rail and fastenings.

Final report on service test on the Illinois Central, offered as information. Continuing with study of corrosion of track structure under special conditions where the corrosion is accelerated ..... page 828

8. Laying rail tight with frozen joints.

Progress report on the service tests of rail laid tight compared to rail laid with normal bolt tension and expansion ..... page 839

9. Critical review of the subject of speed on curves as affected by present-day equipment, collaborating with the AAR Joint Committee on Relation Between Track and Equipment.

No report. Your committee has under consideration the revision of present AREA spiral.

10. Methods of heat treatment, including flame hardening, of bolted rail frogs and split switches, together with methods of repair by welding.

Progress report, presented as information ..... page 862

11. Economies to be gained by the railroads from the more extensive use of AREA trackwork plans.

Final report, presented as information ..... page 870

AREA Bulletin 549, February 1959.

THE COMMITTEE ON TRACK,
W. E. CORNELL, *Chairman*.

Report on Assignment 1

Revision of Manual

G. R. Sproles (chairman, subcommittee), John Ayer, Jr., R. J. Bruce, M. D. Carothers, W. E. Cornell, P. H. Croft, M. J. Hassan, C. C. Herrick, A. F. Huber, H. W. Jensen, L. A. Pelton, Troy West, M. J. Zeeman.

Your committee submits the following recommendations with respect to the Manual:

Pages 5–2–1 and 5–2–2

SPECIFICATIONS FOR SOFT STEEL CUT TRACK SPIKES

On page 5–2–2, Sec. C, Par. 1 (b) reads:

"The head of the full size finished spikes shall bend to the line of the face of the spike, without cracking on the outside of the bent portion."

The present wording was adopted in 1920, and considering the change in the design of spikes, the committee is of the opinion the wording does not cover the intent of the specification with respect to present-day manufacture. The intent of the specification is to eliminate spikes containing forging defects in their throats and should not be concerned with superficial surface disturbances. Bending the large amount of metal in the spike head puts severe tension stresses in the throat fillet, and it can be expected that some superficial metal skin distortion can occur.

Accordingly, the committee recommends that this paragraph of the specifications be changed to read:

"(b) The head of the full-size finished spike shall bend backward to the line of the face of the spike, without showing evidence of forging laps on the surface of the bent portion."

Report on Assignment 3

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

M. J. Zeeman (chairman, subcommittee), R. D. Baldwin, J. P. Barker, W. R. Bjorklund, R. J. Bruce, M. D. Carothers, E. W. Caruthers, H. B. Christianson, J. T. Collinson, W. E. Cornell, E. D. Cowlin, F. W. Creedle, H. C. Fox, R. M. Frey, J. W. Fulmer, M. J. Hassan, A. E. Haywood, A. B. Hillman, A. F. Huber, H. W. Jensen, C. H. Johnson, T. R. Klingel, R. E. Kuston, L. W. Leitze, E. J. Lisy, Jr., C. J. McConaughy, C. E. Peterson, S. H. Poore, J. A. Reed, R. D. Simpson, T. R. Snodgrass, J. B. Taylor, K. H. Von Kampen, S. J. Watson, Troy West, I. V. Wiley, J. B. Wilson, B. J. Worley.

Your committee submits for approval as recommended practice and publication in the Manual (Portfolio of Trackwork Plans) the following three plans:

Plan 791–59—Tables of Practical Gages and Flangeways for Curved Track,

Plan 792A–59—Graph Showing Minimum Gages and Flangeways for Curved Track (Diesel Locomotives),

Plan 792B–59—Graph Showing Minimum Gages and Flangeways for Curved Track (Steam Locomotives).

It also recommends withdrawal of the previous issue of Plans 791–34 and 792–34.

The data on the above three plans were obtained by combining the information in the AAR Engineering Division research report "Track Gage and Flangeway Widths for Operation of Diesel Power on Curved Track" with the data now published in the Portfolio for steam operation only. This research report was presented to the 1958 convention as information and is published in the 1958 Proceedings (Vol. 59) as Appendix 3–d on pages 1011 to 1017.

Your committee also recommends for approval as recommended practice and publication in the Manual (Portfolio of Trackwork Plans) revisions of Par. 33 (b), 33 (c), 33 (d) and 33 (h) of the Specifications for Special Trackwork, Appendix A, page 1, as follows:

Par. 33(b)—Substitute the following for the present wording:

Track gage may be $\frac{1}{16}$" under or $\frac{1}{16}$" over specified gage in completed crossings".

Par. 33 (c)—Substitute the following for the present wording:

"Guard face gage in completed crossings having a specified track gage of 4′ 8½" with specified flangeways 1⅞" wide, or a specified track gage of 4′ 8⅝" with specified flangeways 1⅞" and 2" wide, shall be between 4′ 4⅞" and 4′ 4$\frac{11}{16}$", incl.

"Guard face gage in completed curved crossings other than those which are included in the preceding paragraph shall not be greater than the specified dimension and may be up to 1/8" less than this dimension."

Par. 33 (d)—Substitute the following for the present wording:

"Flangeways in completed crossings may be 1/16" less than the specified width or more than the specified width if required to conform to (b) and/or (c) above, except that in curved crossings the minimum guard check gage from the inner guard line to the outer gage line shall be 4' 6 5/16"."

Par. 33 (h)—Change first sentence to read: "All the above apply to track for steam or diesel locomotive operation".

The above proposed revisions of Par. 33 result in slightly closer tolerances in frog and crossing gages and flangeways, which are thought to be desirable for diesel operation.

Also recommended for approval as recommended practice and publication in the Manual (Portfolio of Trackwork Plans) is a revision of Art. 15, Spring Washers, Appendix A, page 8, of the Portfolio. The proposed revision is to limit Article 15 to cover spring washers for railroad crossings only, instead of for all parts of special trackwork requiring 1¼ in and 1⅜ in diameter bolts. The double-coil type of spring washer designed to meet the reactive load requirements is not needed for turnout frogs and guard rail assemblies. The proposed new Art. 15, to supersede present Art. 15, is as follows:

Article 15. Spring Washers

1501. Material Covered

Spring washers for use in special trackwork.

1502. Manufacture

Spring washers for all bolts of ¾" to 1⅜" diameter, incl., shall be in accordance with the current AREA Specifications for Spring Washers (Manual, Chapter 4, Part 2). Spring washers for 1⅜" diameter bolts for all purposes and for 1¼" and 1⅜" diameter bolts when used with turnout frogs and guard rail assemblies shall have a minimum reaction of 5000 lb. at 0.030" release as specified in the above specifications for the 1⅜" and 1¼" diameter washers. Spring washers for 1¼" and 1⅜" bolt sizes when used in crossing frogs shall comply with the said current AREA specifications except that the following revisions and additions to the specifications shall govern.

Method of Testing for Reactive Load

The reactive pressure tests of the specimens shall be conducted in a compression machine of approved design, equipped with a deflection gage, graduated in 0.001" and located so that readings are taken from approximately the center of the platens. Each specimen shall be preloaded three times to 60,000 lb between hardened steel blocks and completely released. The specimen will then be compressed with the fourth 60,000-lb load and released to a release point, at which release point the reactive load shall be not less than 10,000 lb.

The release point shall be as determined from tests conducted in the manner hereinafter described on six specimens of the design and size of washer involved. Each specimen shall be compressed in the testing machine between an ASA heavy medium-carbon nut with a short length of its bolt as one bearing face and a 4" square steel plate of not to exceed 150 Brinell with a hole drilled in the center 1/16" larger than the nominal bolt diameter as the other bearing face. The faces on both sides of the nut and plate shall be machined or ground for each specimen tested to provide flat and parallel bearing surfaces. The specimen shall be oriented to have one coil end close to the middle of one side of the nut. Load the specimen to 40,000 lb and record the gage reading for that position of the platens. Increase the test load to 60,000 lb. Then

NOTES

ER SHALL IN ALL CASES SPECIFY: The gage and the angeways to be used in crossings and other trackwork units curve and equipment as described in Notes 2 and 3.

TRUCK WHEEL

"

"

"

"

"

"

"

"

"

clusive diesel operation with wheel mounting per Note specify from Table "D" the gage required by the longest wheel base.

clusive diesel operation with trucks having wheels spaced back of flanges 4'–5¼" or 4'–5⅛", see Note "D" for etermination. For convenience in specifying adjusted gages arded curves, comparable gages to those shown in Table re listed in Note 3, below.

mbined steam and diesel locomotive operation specify the om Table "S" preferably per Note "J".

conomy in maintenance of curved crossings, 4'–9" gage not be exceeded.

(A) Data f

(B) Gages maxim 4'–5⅜ 6-whe

RIGID AND	AGE PER R 2(c)		ADJUSTED GAGE FOR GUARDED CURVES PER NOTE 2(b)				
	⅜" B TO B NGEWAYS		WHEELS 4'-5¼" B TO B		WHEELS 4'-5⅛" B TO B		
	L.	OUT. RL.	GAGE	FL'WYS. BOTH	GAGE	FLANGEWAYS IN. RL.	FLANGEWAYS OUT. RL.
5 PAIRS ALL FLANGED DRIVERS SEE NOTE G		2"	4'-8½"	1⅞"	4'-8½"	1⅞"	2"
		2"	4'-8⅝"	2"	4'-8⅝"	2"	2⅛"
	"	2⅛"	4'-8¾"	2⅛"	4'-8¾"	2⅛"	2¼"
	"	2¼"	4'-8⅞"	2¼"	4'-8⅞"	2¼"	2⅜"
	⅜"	2⅜"	4'-9"	2⅜"	4'-9"	2⅜"	2½"
	"	2½"	4'-9⅛"	2½"	4'-9⅛"	2½"	2⅝"
	⅛"	2⅝"					
	4"	2¾"					

"

AYS

Flangeways for various gages and equipment shall be specified above:

"G"	"P"	2
	19'-0"	2
19'-0"		2

CKS

car trucks can be operated on all curves where gages and flangeways suitable for steam or diesel locomotives are

ES

an Basic No. 790 for flangeways and other data when gage widened for curvature.

(E) Da ppendix "A", Section 33, for permissable variations in icture.

(F) Da bl ce

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(G) D

(H) C w

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(I) G d b

(J) G e m

TABLES OF PRACTICAL GAGES AND FLANGEWAYS FOR CURVED TRACK

PLAN NO. 791-59

TABLE D-GAGES — CURVED TRACK — DIESEL LOCOMOTIVES

6 WHEEL TRUCK			4 WHEEL TRUCK	GAGES — DEGREE OF CURVATURE											
	G" GUARDED CURVES	P" UNGUARDED CURVES	10° MAX	33°	30°	28°	26°	24°	22°	20°	18°	16°	14°	12°	10°
TO 34' WHEEL BASE	—	11'-6" & UNDER		4'-8⅛"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"
"	12'-6" & UNDER	OVER 11'-6" TO 12'-1"		4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"
"	OVER 11'-6" TO 12'-1"	" 12'-1" " 12'-8"		4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"	"	"
"	" 12'-1" " 12'-8"	" 12'-8" " 13'-3"		4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"	"
"	" 12'-8" " 13'-3"	" 13'-3" " 13'-10"			4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"
"	" 13'-3" " 13'-10"	" 13'-10" " 14'-5"				4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8½"	"	"
"	" 13'-10" " 14'-5"	" 14'-5" " 15'-0"					4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"
"	" 14'-5" " 15'-0"	" 15'-0" " 15'-7"						4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"
"	" 15'-0" " 15'-7"	—							4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"

(A) Data for Table "D" were derived from Plan Basic No. 729A

(B) Gages are given to the nearest one-eighth inch and are based on maximum wheel diameter of 42", spaced back to back of flanges 4'-5⅛", and average total lateral play in middle and end axles of 6-wheel truck amounting to ¾".

(C) For gages for trucks having an average total lateral play in middle and end axles other than ¾", see Note 4(b) Plan Basic No. 792A.

(D) For gages for trucks having wheels spaced back to back of flanges 4'-5⅛" or 4'-5⅛", see Note 1(c) Plan Basic No. 729A for "UNGUARDED CURVES", and Note 4(d) Plan Basic No. 792A for "GUARDED CURVES".

TABLE S — GAGES — CURVED TRACK — STEAM LOCOMOTIVES

RIGID WHEEL BASE OF LOCOMOTIVE AND NUMBER OF FLANGED DRIVERS						GAGES — DEGREE OF CURVATURE											
5 PAIRS OR MORE FLANGED DRIVERS SEE NOTE G	5 PAIRS APPROPRIATE CENTER DRIVER BLIND	4 PAIRS ALL FLANGED DRIVERS	3 PAIRS HALF FLANGED DRIVERS	2 PAIRS ALL WHEEL BASES		33°	30°	28°	26°	24°	22°	20°	18°	16°	14°	12°	10°	8°	6°
			"G" "P"	SEE NOTE F		4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"
				11'-0"	WHEEL BASE	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"	"	"
				11'-0" 11'-6"	"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"	"
				11'-6" 12'-0"	"	4'-9⅛"	4'-9"	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"
			G" P"	12'-6" 13'-0"	"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9⅛"	4'-9"	4'-8⅞"	4'-9⅜"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"	"
			15'-0"	13'-6" 14'-0"	"		4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"
			15'-0"	14'-0" 15'-0"	" B			4'-9½"	4'-9⅜"	4'-9¼"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8½"	"	"
		G" P"	16'-0"	14'-0" 15'-6"	"				4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"
			19'-0"	17'-0" 17'-6"	" A					4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"
			19'-0"	20'-0" 17'-6"	18'-0" 16'-0"	"					4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"
G" P"		22'-0"	21'-6"	18'-0"	19'-0"	"					4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	
		19'-0"	21'-0"	22'-6"	19'-0"	"						4'-9½"	4'-9⅜"	4'-9¼"	4'-9"	4'-8⅞"	4'-8⅝"	4'-8½"	
19'-0"		22'-6"				"							4'-9½"	4'-9⅜"	4'-9⅛"	4'-9"	4'-8¾"	4'-8½"	

(E) Data for Table "S" were derived from Plan Basic No. 792B.

(F) Data for column "2 pairs all wheel bases" are applicable to locomotives with one or more pairs of blind center drivers. "All wheel bases" refers to practical limit of approximately 14'0" measured from center to center of outside flanged drivers.

(G) Drivers on floating axles are not counted as flanged drivers nor in the rigid wheel base.

(H) Columns "P" give maximum wheel bases for plain unguarded curves and columns "G" give maximum wheel bases for guarded portion of curves to be operated on gages and degrees of curvature as per table.

(I) Gages are given to the nearest one-eighth inch with an allowance of approximately ⅛" for 3 pairs of drivers, and 1/4" to 3/16" for 4 pairs, and ⅛" to ¼" for 5 pairs, as total gain in lateral play at journal-boxes and tight setting of outside drivers.

(J) Gages per Series "A" may be used for general conditions in main line tracks unless it is known that extra large locomotives operate over it. Gages per Series "B" may be used in yards and sidings where main line locomotives do not operate.

NOTES

1—GENERAL

PURCHASER SHALL IN ALL CASES SPECIFY: The gage and the width of flangeways to be used in crossings and other trackwork units to suit the curve and equipment as described in Notes 2 and 3.

2 GAGE

(a) For exclusive diesel operation with wheel mounting per Note "B", specify from Table "D" the gage required by the longest truck wheel base.

(b) For exclusive diesel operation with trucks having wheels spaced back to back of flanges 4'-5⅛" or 4'-5⅛", see Note "D" for gage determination. For convenience in specifying adjusted gages for guarded curves, comparable gages to those shown in Table "D" are listed in Note 3, below.

(c) For combined steam and diesel locomotive operation specify the gage from Table "S" preferably per Note "J".

(d) For economy in maintenance of curved crossings, 4'-0" gage should not be exceeded.

WIDENED GAGE PER NOTE 2(a) OR 2(c)			ADJUSTED GAGE FOR GUARDED CURVES PER NOTE 2(b)					
WHEELS 4'-5⅜" B TO B			WHEELS 4'-5¼" B TO B			WHEELS 4'-5⅛" B TO B		
GAGE	FLANGEWAYS		GAGE	FLWYS.		GAGE	FLANGEWAYS	
	IN. RL.	OUT. RL.		BOTH			IN. RL.	OUT. RL.
4'-8⅝"	1⅞"	2"	4'-8½"	1⅞"		4'-8½"	1⅞"	2"
4'-8¾"	2"	2"	4'-8⅝"	2"		4'-8⅝"	2"	2⅛"
4'-8⅞"	2⅛"	2⅛"	4'-8¾"	2⅛"		4'-8¾"	2⅛"	2¼"
4'-9"	2¼"	2¼"	4'-8⅞"	2¼"		4'-8⅞"	2¼"	2⅜"
4'-9⅛"	2⅜"	2⅜"	4'-9"	2⅜"		4'-9"	2⅜"	2½"
4'-9¼"	2½"	2½"	4'-9⅛"	2½"		4'-9⅛"	2½"	2⅝"
4'-9⅜"	2⅝"	2⅝"						
4'-9½"	2¾"	2¾"						

3—FLANGEWAYS

Width of Flangeways for various gages and equipment shall be specified as listed above:

4—CAR TRUCKS

Two axle car trucks can be operated on all curves where gages and widths of flangeways suitable for steam or diesel locomotives are specified.

5—REFERENCES

(a) See Plan Basic No. 790 for flangeways and other data when gage is not widened for curvature.

(a) See Appendix "A", Section 33, for permissable variations in manufacture.

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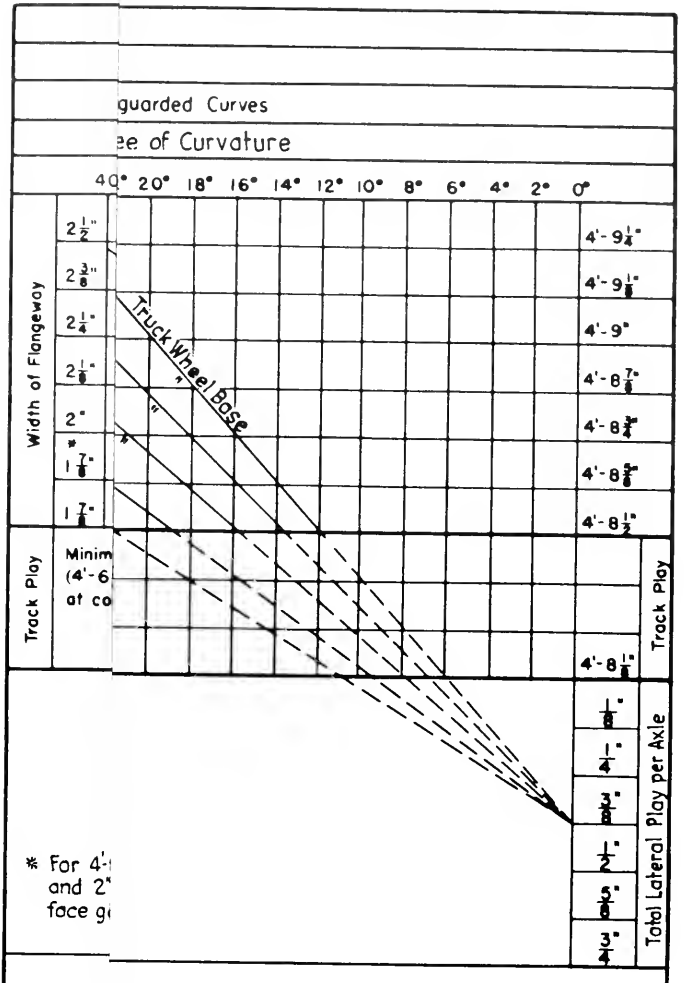
TABLES OF PRACTICAL GAGES AND FLANGEWAYS FOR CURVED TRACK

PLAN NO. 791-59



1—DA

(a)

(b)

in Railway Engineering Association

(c)

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2—Pos
ver
EX

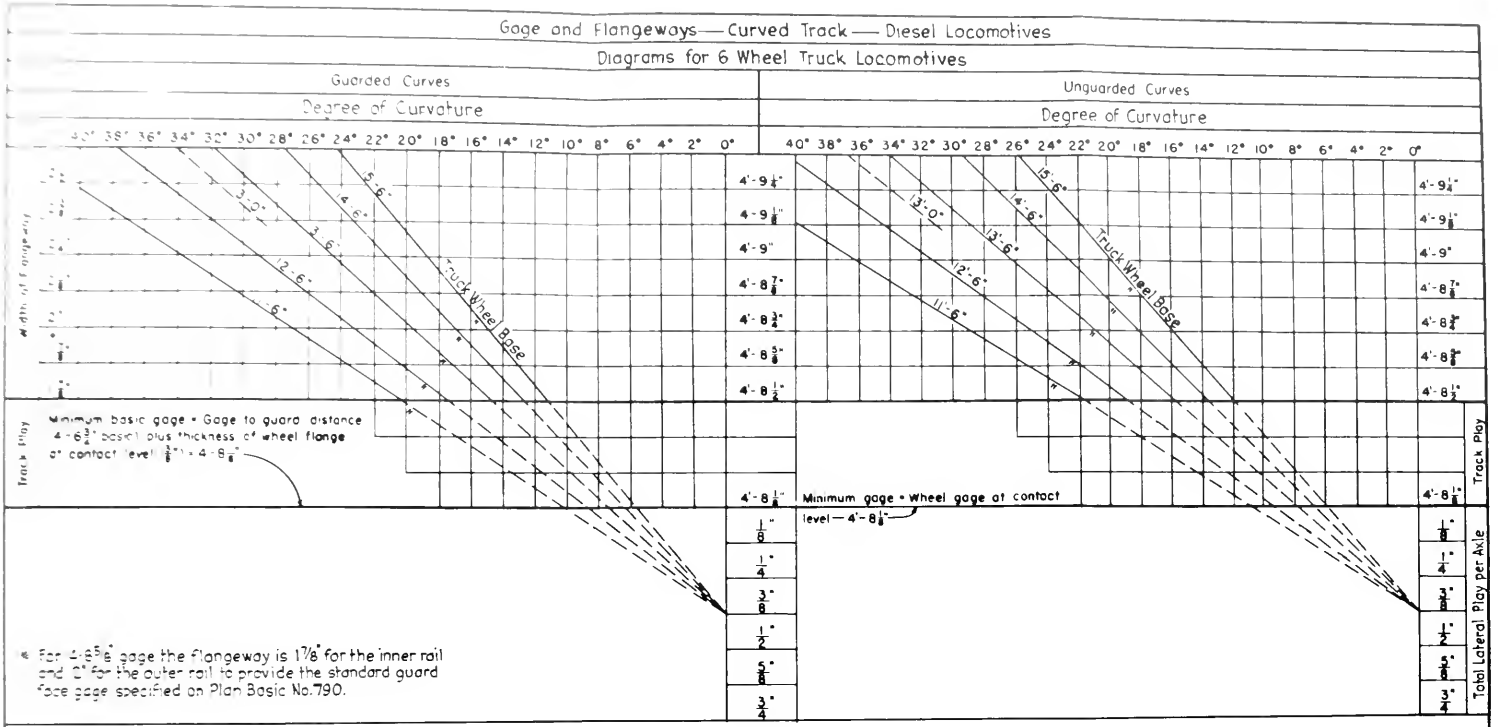
RAPH SHOWING MINIMUM
GAGES AND FLANGEWAYS
FOR CURVED TRACK
(Diesel Locomotives)

3—For
Pla

4—IN

(a)

PLAN NO. 792A-59



NOTES

1—DATA AND INFORMATION.

(a) Diagrams are based on maximum wheel diameter of 42", back to back of flanges 4'-5 3/8" and average total lateral play in middle and end axles of 6-wheel truck amounting to 3/8".

(b) Although the diagrams include the maximum gage of 4'-9 1/4", most of the road diesels when hauling trains are limited to a maximum curvature of 21 degrees or 22 degrees.

(c) Four wheel truck diesels with a maximum truck wheel base of 10'-0" do not require widening of track gage on curves to reach the limiting curve of the locomotives.

2—Position of intersection between diagonal wheel base line and vertical degree-line with reference to horizontal lines gives the EXACT MINIMUM GAGE required.

3—For "PRACTICAL GAGES recommended," see Table "D", Plan Basic No. 791.

4—INTERPOLATION—For other Gages.

(a) Each diagram may be interpolated for intermediate lengths of wheel bases and average total lateral play in middle and end axles of truck averaging other than 3/8".

4—(continued)

(b) Track gage for other than 3/8" average total lateral play in middle and end axles of truck, can be determined graphically in either diagram by drawing a line parallel with the curve for a given truck wheel base and starting the line at the new value of average total lateral play per axle.

(c) Track gage for UNGUARDED CURVES, for trucks having wheels spaced back to back of flanges 4'-5 3/4" or 4'-5 3/8", can be determined by adding the increased amount of track play, 1/8" or 1/4", to the average total lateral play per axle.

(d) Track gage for GUARDED CURVES, for trucks as outlined in Note 4(c) shall be equal to the flangeway determined from the graph plus the standard guard check gage 4'-6 3/8" required for car trucks. This width of flangeway shall be used for the inner rail for all trucks and also for the outer rail for those having wheels spaced back to back of flanges 4'-5 1/2", but the width of flangeway of the outer rail is increased 1/8" for trucks having wheels spaced back to back of flanges 4'-5 3/8", except when the gage on the graph is 4'-8 1/2". Comparable adjusted gages and widths of flangeways are listed in Note 3, Plan Basic No. 791.

5—For basic information and formulas used in this analysis, see AREA Proceedings, Volume 59, Pages 1011 to 1017.

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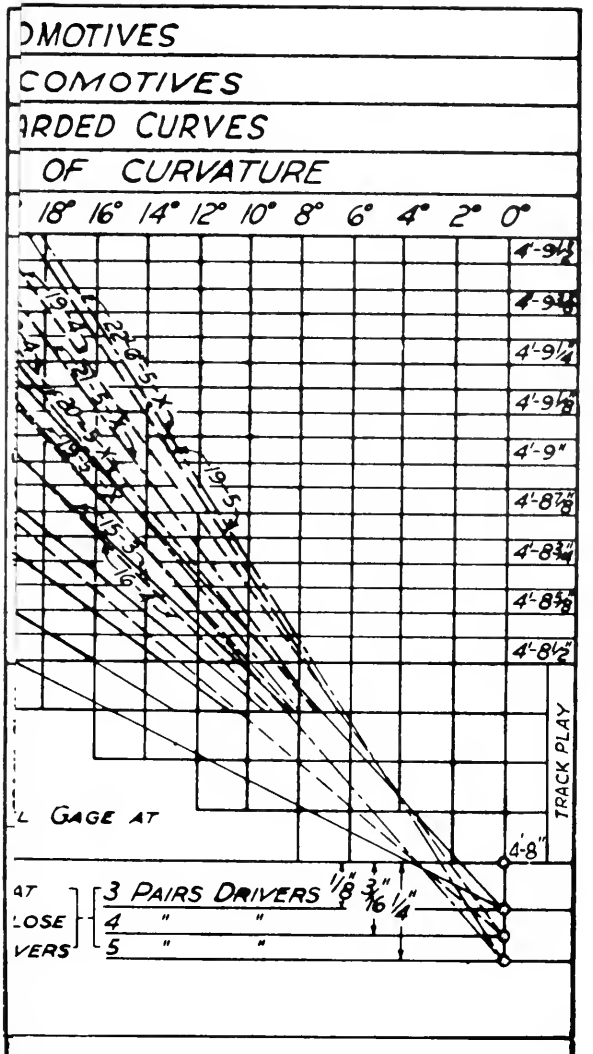
GRAPH SHOWING MINIMUM GAGES AND FLANGEWAYS FOR CURVED TRACK
(Diesel Locomotives)

PLAN NO. 792A-59



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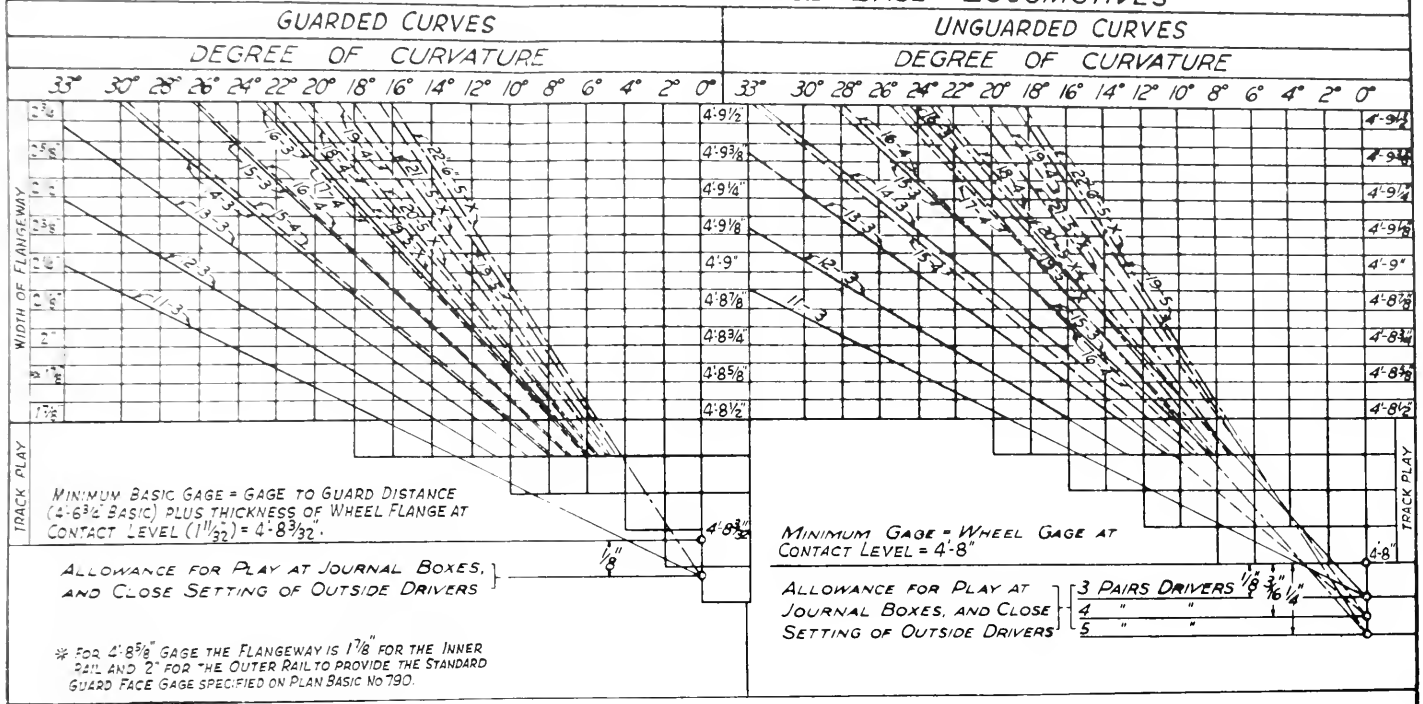
GRAPH SHOWING MINIMUM GAGES AND FLANGEWAYS FOR CURVED TRACK

(Steam Locomotives)

PLAN NO. **792B-59**

GAGES AND FLANGEWAYS—CURVED TRACK—STEAM LOCOMOTIVES

DIAGRAMS FOR RIGID WHEEL-BASE LOCOMOTIVES



NOTES

1—DATA AND INFORMATION.

(a) Indication on diagonal lines of length of wheel base and number of drivers.

Rigid Wheel Base in Feet	No-Ft-3	3 Pairs, All Flanged Drivers.
" " " " "	No-Ft-4	4 Pairs, " " "
" " " " "	No-Ft-5	5 Pairs, " " "
" " " " "	No-Ft-5X	5 Pairs, Center Driver Blind.

(b) Front and rear trucks must have sufficient swing for degree of curve to operate on gage and widths of flangeways given.

2—Position of intersection between diagonal wheel base line and vertical degree-line with reference to horizontal lines gives the EXACT MINIMUM GAGE required.

3—For "PRACTICAL GAGES recommended", see Table "S", Plan Basic No. 791.

4—Each diagram may be interpolated for other lengths of wheel bases.

5—For basic information and formulas used in this analysis, see AREA Proceedings, Volume 22, Pages 679 to 686 and Volume 23, Pages 614 to 616.

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GRAPH SHOWING MINIMUM GAGES AND FLANGEWAYS FOR CURVED TRACK (Steam Locomotives)

PLAN NO. 792B-59

release the platens until the distance between them is 0.030" greater than the gage reading taken at the 40,000-lb load and record the reactive load remaining. The same specimen after two additional preloads of 60,000 lb between hardened steel blocks shall then be released from a load of 60,000 lb to this same reactive load and the release distance recorded. The average release distance so obtained for the six specimens shall constitute the release point for all reactance acceptance tests of that design and size of washer.

Ductility Test

This test shall be conducted in accordance with Art. 4, Par. (a) of the current specifications, except double-coil washers shall first be cut off to form a single coil washer.

Proportion of Tests

Art. 5 of the current specifications shall govern, except that three specimens will be tested for each lot of 1000 or more of finished spring washers.

Your committee also recommends approval of the following minor revisions in Appendix A:

Page 3, Par. 405 (e). Insert "more" between "not" and "than" in second line.

Page 4, Par. 409. Change second word in first line from "or" to "of".

Page 6, Par. 905. Change second line to read "the specifications referred to in Paragraph 902." Par. 906 (a). Change second line to read "Shapes shall be within the limits of the specification referred to in Paragraph 902." Par. 1002 (a). Insert "process" after "hearth". Par. 1006 (c). Change dimension ($\frac{1}{8}$") to ($\frac{3}{16}$").

Page 7, Par. 1301. Substitute the following: "Rolled steel joint bars of standard design for joints in rails of standard T-rail section".

New Errata Section for Portfolio of Trackwork Plans

We invite your attention to another matter which has received extensive consideration by your committee—namely, the best and most economical way to take care of minor inconsistencies or errors on the plans in the Trackwork Portfolio. The method of handling this matter is considered to be editorial and as such does not require convention approval. The subject was taken up with the executive secretary of the Association who suggested that the procedure for handling these minor revisions be described in detail as part of the "Foreword" on page 1 of the Table of Contents. We acknowledge our appreciation for his suggestion.

For your ready information, we are submitting the new Foreword, as written by the executive secretary, which describes how these minor errors and inconsistencies will be handled in a new "Errata Section" at the end of the Table of Contents.

FOREWORD

This Portfolio of Trackwork Plans and Specifications is a part of the Manual of Recommended Practice of the American Railway Engineering Association and is published separately, in loose-leaf form, for convenient use and to facilitate the making of additions and revisions. It is sponsored by Committee 5—Track, of the Association, the deliberations of which, respecting the contents of the Portfolio, are reported in the Annual Proceedings of the Association. The Standardization Committee of the Manganese Track Society collaborated in the preparation of these plans and specifications.

The Portfolio contains plans for switches, frogs, crossings, and their appurtenances,

together with a Table of Contents, specifications and definitions. Each plan has a Basic number, followed by a serial number to indicate the year of its adoption or of its latest revision. A footnote in the lower left-hand corner shows the dates of previous actions on the plan by the Association. A few plans are included as information only, for convenient reference.

These plans and specifications are applicable to tee rails weighing 90 lb per yard and heavier, with preference given to rail sections and joint bar designs and drillings recommended by the Association. Each trackwork item can be completely specified by reference to its Plan number, and the bill of material when necessary, provided the rail section and joint bar details are stated. The alternate constructions presented on some of the plans can be incorporated in the item by reference thereto.

Periodic Supplements to Keep Portfolio Up to Date

Supplements to the Portfolio are issued periodically in the form of additional or revised sheets to incorporate new plans or revisions in existing plans adopted by the Association, and each such Supplement is accompanied by a revised Table of Contents to show reference to any new plans and changes in serial numbers of revised existing plans.

Important to Check Errata Section for Latest Revisions Not Shown on Plans

To avoid the expense, and cost to holders of the Portfolio, of reissuing plans in periodic Supplements merely to correct minor errors or to incorporate minor revisions or additions that may become necessary by the adoption of other plans, page 3 of the Table of Contents includes an "Errata Section" which lists the plans requiring correction and, for each plan, shows the corrections to be made.

To direct attention to the plans requiring such revisions, the letter "E", followed by a serial number indicating the year the revision was approved by the Association, is shown after the plan *Basic* number in the Table of Contents. For example, the designation 190–55 E–59 in the Table of Contents indicates that Plan Basic No. 190, which was adopted or revised in 1955, must be corrected by the user as indicated in the Errata Section to bring it up to date (1959), unless Plan 190, itself, already bears the printed designation E–59, which means that the corrections called for in the Errata Section have already been incorporated in the plan. Accordingly, to avoid oversight, owners of the Portfolio are asked to show the "E" designation, where called for, directly on copies of the plans affected (unless any of these plans already bear this designation in printed form), or preferably, in addition, to bring these plans completely up to date by making on them the corrections shown in the Errata Section.

When it becomes necessary to reprint any of these plans to incorporate major revisions or additions, the present minor revisions called for in the Errata Section will be incorporated at the same time, and new sheets bearing up-to-date serial numbers will be issued to all Portfolio owners in a Supplement, to replace existing comparable sheets. At this time all reference to these specific plans will be removed from the Errata Section.

Having acquainted you with the "Errata Section", we now recommend for your approval the adoption of the following data to be shown in the Errata Section of the Portfolio. These constitute minor revisions on 32 plans.

Plan No.

190–55 E–59 Add Plans Basic No. 181 and 220 in note.

213–52 E–59 Substitute for the last sentence in Note 1, the following:

"RAIL AND JOINT BARS. Purchaser shall specify weight and designation of rail section and joint drilling and shall supply complete details of joint bars."

320–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

322–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

323–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

324–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

401–55 E–59 In Note 2—Fillers,substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

405–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

407–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

408–55 E–59 In Note 2—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

505–40 E–59 In Note 7 delete Plan Basic No. 503.

600–55 E–59 In Note 5—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

621–55 E–59 In Note 4—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

671–55 E–59 On Section D–D, change upper dimension line indicating height of casting, from top of wing to top of point area.

701–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

702–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

703–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

704–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

705–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

706–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

708–55 E–59 In Note 2 (d)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

710–55 E–59 In Note 2 (d)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

755–55 E–59 In Note 2 (c)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

757–55 E–59 In Note 2 (c)—Fillers, substitute phrase "Per Plan Basic No. 325" for "preferably single groove section".

Plan No.

701–55 E–59 In Note 2 (d)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

768–55 E–59 In Note 2 (d)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

769–55 E–59 In Note 2 (d)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

771–55 E–59 In Note 2 (e)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

772–55 E–59 In Note 2 (e)—Fillers, substitute phrase "Per Plan Basic No. 325" for "preferably single groove section".

773–55 E–59 In Note 2 (e)—Fillers, substitute phrase "per Plan Basic No. 325" for "preferably single groove section".

782–55 E–59 In Note 2 (e)—Fillers, second sentence, substitute phrase "per Plan Basic No. 325" for "preferably single groove section". On Section C–C show 1⅜" height from top of casting to outer edge of upper fishing surface and the angle of this surface as 14°.

783–55 E–59 In Note 2 (e)—Fillers, second sentence, substitute phrase "per Plan Basic No. 325" for "preferably single groove section". On Section C–C show 1⅜" height from top of casting to outer edge of upper fishing surface and the angle of this surface as 14°.

The collaboration of the Standardization Committee of the Manganese Track Society in the above recommended changes and additions, as well as in other subjects under consideration for future action, is gratefully acknowledged.

Your committee also submits, as information,the following report prepared by the research staff of the Engineering Division, AAR: Appendix 3–a—Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill.

Appendix 3–a

Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill.

This report, presented as information, concerns the performance of designs of manganese steel castings in the crossings between the double-track lines of the Baltimore & Ohio Chicago Terminal Railroad and the Atchison, Topeka & Santa Fe Railway at McCook, Ill., 13 miles from the Santa Fe passenger terminal in Chicago.

Foreword

Since June 1957 (Vol. 59, 1958, page 1010), only one of the three 1952 castings has remained in service. All of the designs that have been investigated since 1943 were of the solid manganese type for the end position of the crossings, having a height of 6¼ in, the same as 110 RE rail, and an angle of 75 deg 48 min. The Santa Fe tracks carry high-speed passenger and freight traffic and the B&OCT hauls heavy freight traffic at moderate speeds.

Ramapo Deepened Flangeway Casting

When the Ramapo depth-hardened deepened flangeway casting was inspected on August 12, 1958, its total service was 5.85 years. This casting is located in the same

corner of the crossing in the westward main tracks of both railroads. The test crossing is supported on the longitudinally framed timbers placed in 1952. There was a total of 26 in of flangeway cracks, including 6 in. in the flangeway fillets. Corresponding cracks reported last year were 18 in, including 6 in. in the fillets. Most of the cracks were in the flangeway floor near the center line. The casting had one crack on the running surface of the Santa Fe receiving corner, which extends down the side wall 2 in to the hole cast in the wall. The crack on top was repaired and was not visible in the path worn by the wheel tread. This casting can be repaired by recapping the two receiving corners and should be serviceable for several months.

Acknowledgement

The Association is grateful for the splendid cooperation and assistance rendered by the B&OCT for almost 15 years and extends thanks to the suppliers who by their keen interest and cooperation have greatly improved the serviceability of Hadfield manganese steel castings.

Report on Assignment 4

Prevention of Damage Resulting From Brine Drippings on Track and Structures

Collaborating with Committee 15, and Mechanical Division, AAR

W. E. Griffiths (chairman, subcommittee), J. Ayer, Jr., M. C. Bitner, H. F. Busch, W. E. Cornell, P. H. Croft, L. W. Green, C. C. Herrick, J. S. Parsons, Troy West.

This is a progress report, submitted as information, on an investigation seeking to find and evaluate non-toxic brine corrosion inhibitors for use in refrigerator car bunkers. This work is being conducted for your committee at the AAR Research Center by S. K. Coburn, research chemist, assisted by K. J. Morris, chemist, under the general direction of G. M. Magee, director of engineering research.

Inhibitors for Brine Corrosion

The use of small quantities of materials, either pure compounds or proprietary mixtures of pure compounds, as corrosion inhibitors is an attractive means for mitigating corrosion. An examination of the many forms of corrosion and the many substances which are corrosive reveals what appears to be a vast number of distinctly different situations until they are classified. Of the substances considered to be aggressive corroding agents, such as sulfuric acid, used in steel pickling; fuming nitric acid, used to power rockets and missiles; hydrochloric acid, used to disintegrate oil well obstructions as well as to clean out heat exchanger tubes in chemical processing plants; and other chemicals of commerce, many can be inhibited for the most part. But the mildly neutral sodium chloride—table salt or rock salt—is the most aggressive substance of all. It carries out its corrosive action at a slower rate than these other substances, but our knowledge and our capacity to minimize its aggressive tendencies have not been too successful. Even such high-priced alloy steels such as the stainless steel family are vulnerable to pitting by salts such as sodium chloride and sodium sulfate.

In previous reports methods for the testing and evaluation of the various materials selected for study have been detailed. Many substances, both individually and in combination, have been studied in this fashion. After examining the obvious combinations

of water-soluble inorganic compounds and mixtures with interesting results, it was concluded that the economics of the various systems would not be advantageous. More recently a number of organic chemicals were investigated. These were materials which have been found successful in down-well applications in the oil fields. Experimental data from a number of these tests are described in the AREA Proceedings, Vol. 59, pages 1018–1028.

Recently several new materials have been made available in experimental quantities. One of these is derived from the waste water originating in a corn and soybean refining process. Its most attractive feature is its lack of toxicity. Its most unattractive feature is that it operates best in a somewhat acid media. Several compounds of the series are available, which will be thoroughly studied in order to utilize the best of them. Another compound which showed possibilities in some classified research work during World War II is now available. In combination with other materials, whose toxicity is somewhat in doubt, it has performed interestingly and will be carefully studied.

During the past year progress has been steady in readying our newly received cycling relative-humidity accelerated-corrosion cabinet, which will soon be ready for calibration tests.

Tie Plate Corrosion Resistance

Among other activities undertaken by the corrosion research staff is the joint examination of tie plates on the Pennsylvania Railroad. It has been observed for some time that the low-alloy high-strength steels, recognized by such trade names as Cor-Ten, Mayari R, Yoloy, and the like, are capable of withstanding certain corrosive atmospheres. Among the reasons for this resistance is the presence of a small amount of nickel and copper (in a concentration above 0.20 percent). The Pennsylvania Railroad placed some of these tie plates in track in both a rural and an industrial area approximately 12 years ago. The industrial area is located on a river in an industrial valley opposite two steel mills and a coke plant, as shown in Fig. 1. The tie plates with low copper concentrations were characterized by deep pits and thin sections. The tie plates with the higher copper content were considerably less effected by the industrial atmosphere. This is evident in Figs. 2a and 2b. When the plates are placed one above the other, the contrast in section is readily observable. When the plates are placed adjacent to one another, the severe surface pitting in the plate of low copper content is evident. Fig. 3 shows the contrasting condition in track. The plate in the foreground has little copper and shows a knife edge condition, while the plate marked by the rock and those beyond reveal a thicker section, approximating the original dimensions and relatively unaffected on the surface.

In the rural forested area the distinction is not as great, though there is evidence to show that the presence of a higher concentration of copper makes the plate more resistant to atmospheric corrosion.This might be attributed to the fact that some half dozen years earlier a paper mill 15 miles away had ceased to pollute a small nearby stream. However, during that period sulfite wastes undoubtedly contributed some sulfur dioxide to the atmosphere, resulting in the corrosion of the tie plates of lower copper content, shown in Fig. 4. The regular PRR specified tie plate is on the left side marked with a "P". The high-copper-content tie plate, on the right, shows up clearly with the manufacturer's markings.

The basis for carrying out this test was predicated on the observations made in this country and in the industrial areas of England that atmospheres containing sulfur in any form tend to combine chemically with the copper in the steel (when present

Fig. 1—Industrial valley characterized by two steel mills and a coking plant.

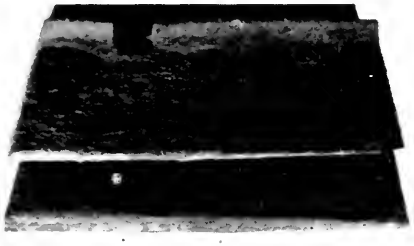


Fig. 2a—Contrasting thickness in section between tie plates of low and high copper concentrations.

Fig. 2b—Contrasting surface appearance between tie plates of low and high copper concentrations.

in concentrations above 0.20 percent) to form a series of copper compounds. Such copper compounds have been isolated from rust by a number of investigators. The relatively thin, dark, tightly adherent rust scale which forms acts as a protective coating over the steel and minimizes further corrosion. Sulfur-laden atmospheres, of course, are common to steel mill and paper mill environments.

Laboratory Evaluation of Copper-Bearing Steel

Also completed during the course of this year's work was a controlled laboratory investigation to determine whether a low-alloy high-strength type of steel might serve satisfactorily in the presence of fairly high concentrations of brine drippings.

Specimens of such a steel along with specimens from a hot-worked high-carbon rolled tie plate of standard 7-A design were subjected to the standard room temperature

Fig. 3—Thin corroded plate in foreground (low in copper) followed by thick, non-corroded plates in background (high in copper).

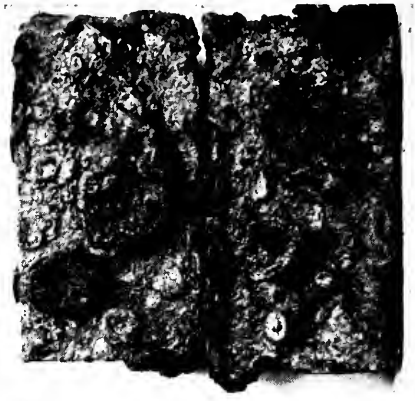


Fig. 5—Hot-worked tie plate steel and low-alloy high-strength steel after 90-days exposure.

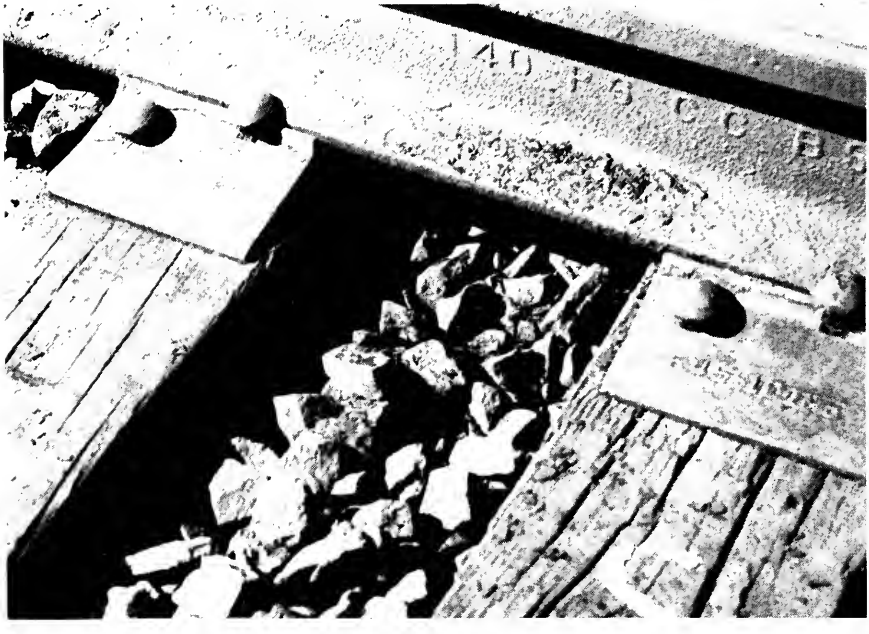


Fig. 4—Low copper containing plate (P) and high copper containing tie plate (c) in rural area.

cycling relative humidity brine corrosion test for periods of 45 and 90 days. As a control, a medium-carbon steel used in routine inhibitor evaluation testing was used. The specimens were immersed twice daily for a few minutes in a 5-percent brine solution and placed in containers through which the relative humidity was varied from 80 to 20 percent. At night the specimens were exposed to 100 percent relative humidity. On Fridays they were rinsed in distilled water simulating the washing action of rain and allowed to stand in an atmosphere of 100 percent relative humidity. The partial compositions of steels tested are shown in Table 1.

TABLE 1—COMPOSITIONS OF STEELS EVALUATED AGAINST BRINE CORROSION

	Carbon	*Manganese*	*Chromium*	*Nickel*	*Copper*
Hot-Worked Tie Plate Steel	0.81	0.88	0.05	Trace	0.18
Low Alloy High-Strength Steel	0.09	0.40	0.76	0.14	0.25

After each of the exposure periods separate groups of specimens were descaled and their weight losses determined. The data follow in Table 2.

TABLE 2—WEIGHT LOSS FOR CORRODED SPECIMENS

	Average Weight Loss, Percent, After	
	45 Days	*90 Days*
Control, Medium-Carbon Steel	15.5	25.5
Hot-Worked Tie Plate Steel	14.5	27.2
Low-Alloy High-Strength Steel	14.3	25.6

It is clearly evident from the data in Table 2 and observations of the specimens in Fig. 5 that the variation in concentration of such elements as copper, nickel, and chromium contributed nothing toward increasing the resistance of the steel in question against liquid brine drippings. It is possible that such compositions might be capable of increased resistance against a brine atmosphere, such as occurs in an area adjacent to the ocean. Such observations have been made with substances like Cor-Ten, Mayari R and Yoloy in the test racks at Kure Beach, N. C.

Rail Corrosion in Tunnels

A condition was investigated in a tunnel in the Northwest in which one entrance fronts on a body of salt water and the remainder of the tunnel proceeds some 5100 ft in a semi-circle to the station. It contains a reverse curve and thus is not "open" to full natural ventilation. Aggravating the situation is a 0.2 percent up grade leading to the center of the tunnel and a similar down grade out of the tunnel. There often are leaks from the ceiling of the tunnel, resulting in a considerable flow of water. The relative humidity ranges from 65 to 90 percent for the greater part of the year. As a result rail life has been reduced considerably due to conditions which are optimum for stress corrosion failures. Figs. 6a, 6b and 6c show side, top and bottom views of a corroded section of rail. Fig. 6a illustrates the pitted regions in the web area which lead to stress fractures. Fig. 6b shows an unusual form of head corrosion. In Fig. 6c there is an example of severe pitting in the rail base.

In an effort to reduce the rate of corrosion an examination was made to determine the feasibility of applying cathodic protection, since certain requirements for such an application were present. Unfortunately, the necessary prerequisites for such an application were not always present and this concept was ruled out. The current approach was to use recognized protective coatings applied to surfaces prepared in accordance with the recommendation of the Steel Structures Painting Council. A neoprene-based

Fig. 6a—Pitted rail section.

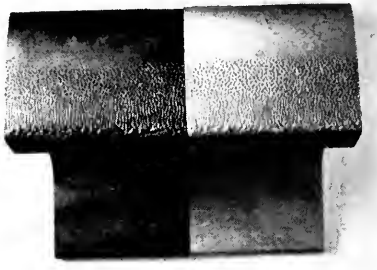


Fig. 6b—Unusual pitting corrosion on head of rail.

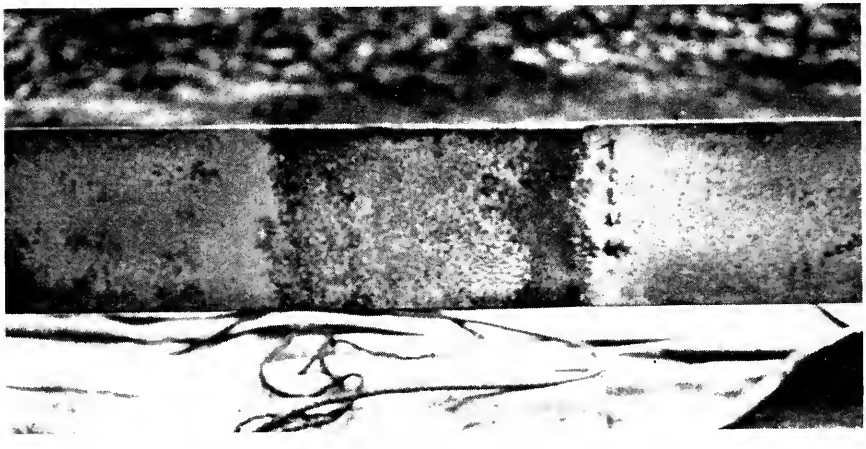


Fig. 6c—Pitted rail base.

coating was selected for application to the rails after careful laboratory evaluation by the test department of the railroad involved. In addition, three other coating systems were applied to a few test rails based on the recommendations of the chemical research staff of the AAR Research Laboratory.

Some 70 rails were sandblasted almost to white metal, as shown in Fig. 7, and treated immediately with a neoprene primer. This was followed several hours later by the neoprene topcoat. Several similarly sandblasted rails then were coated with a pipeline enamel. Another group of rails was coated with a wash primer of the type containing zinc tetroxychromate and a butyryl resin followed by a phenolic-based topcoat. The final test paint was an asphalt-derived vehicle reinforced with corrosion inhibitors and mixed with about 25 percent by weight of flake aluminum. This paint could be

Fig. 7—Sandblasting rust covered and painted rail.

Fig. 8—Painted rail in foreground containing aluminum pigment. Painted rail in background coated with pipeline enamel.

called a non-paint paint since it does not dry by the conventional forms of oxidation and polymerization. It is characterized by the fact that it resists abrasion yet can be removed merely by wiping with a solvent-soaked wiping cloth. Some of the painted test rail can be seen in Fig. 8. The test specimens will be inspected periodically.

Report on Assignment 6

Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

J. S. Parsons (chairman, subcommittee), J. E. Armstrong, Jr., F. J. Bishop, M. C. Bitner, E. W. Caruthers, H. B. Christianson, W. E. Cornell, E. D. Cowlin, F. W. Creedle, R. G. Garland, A. E. Hinson, L. H. Jentoft, T. R. Klingel, L. W. Leitze, E. J. Lisy, Jr., C. J. McConaughy, M. P. Oviatt, J. A. Reed, M. K. Ruppert, J. M. Salmon, Jr., T. R. Snodgrass, R. E. Tew, Troy West.

This is a progress report, presented as information, covering the service test installation of hold-down fastenings, tie pads, etc., on the Louisville & Nashville Railroad near London and East Bernstadt, Ky.

Foreword

These tests are being conducted primarily for the purpose of determining the effectiveness and economy of various types of hold-down fastenings, tie pads, etc. as related to tie life, regaging and readzing curves. The original test sections in the northward main between London and East Bernstadt were installed in August 1947 and are described in the Proceedings, Vol. 50, 1949, pages 595–623. The traffic density was approximately 20 million gross tons annually through 1953 and 15 million gross tons per year since 1953. The line was completely dieselized in 1956. Progress of the test, including additions and revisions, is contained in subsequent reports, the last previous one being in Vol. 59, 1958, pages 1035–1056. Fig. 1 and Table 1 show the location and description of all the test sections on the two 4½-deg curves and tangent track between East Bernstadt and London. Fig. 2 and Table 2 show similar information for the 5-deg curve at the East Bernstadt depot.

Additions and Changes in 1958

Section 04

Bird 5-ply coated tie pads and Bernuth, Lembcke Company, Inc., gage lock spikes and tie plate lock spikes were applied to three 39-ft rail lengths on the 5-deg 36-min curve in the northward main track 0.5 mile north of East Bernstadt, using existing creosoted oak ties and 13-in double-shoulder tie plates, as shown in Fig. 3. The plates on the east (outer) rail were flat bottom and those on the west (inner) rail were compression bottom with ¾-in square anchor holes instead of present design of $1\frac{1}{16}$ in square. Prior to application of the pads, the plates were removed, spike holes plugged and the tie surfaces hand adzed as needed. Type LD jute pads were applied on the north 35 ties and SD duck and burlap pads on the south 37 ties. Holes were then bored with a Raco machine so as to reverse the stagger from that of the cut spikes removed. Two gage lock spikes and two tie plate lock spikes were then hand driven in each plate. The track was in good gage and line, having been relaid with new 132 RE rail with 6-hole joint bars on existing tie plates in March 1958 and surfaced out-of-face on crushed limestone ballast in July 1958.

Section 05

This section, established for control, is south of and adjacent to section 04 in the northward track on the 5-deg 36-min curve. The rail is 132 RE on 13-in double-

shoulder tie plates with two cut spikes each for line and anchor. The rail, tie and ballast conditions are comparable to those in section 04, with which comparison of track gage will be made based on initial measurements taken September 18, 1958.

Section 38

Bird 5-ply coated pads were installed on 48 new ties in the 5-deg curve at East Bernstadt, on August 26, 1958, replacing the entire section 38 containing Achuff sisal fiber pads, but reusing the 14-in double-shoulder tie plates. The construction is similar to that in section 04, shown in Fig. 3. The north 24 ties have type LD jute pads and the south 24 ties type SD duck and burlap pads. Two each of gage lock spikes and anchor lock spikes were used for line and anchors. The Achuff pads released were in poor condition and no longer useful for test purposes, and it was felt that the section could be better used to test a combination of the Bird pads and Bernuth, Lembcke lock spikes.

Section 58

Railroad Rubber Products, Inc., 7- by 9¼-in double-shoulder canted rubber tie plates, Fig. 4, were installed August 27, 1958, on 24 new creosoted oak ties with four cut spikes for line under 131 RE rail, north of and adjacent to section 52 in the tangent south of the short 4½-deg curve.

Section 28

Tire-carcass double-coated pads manufactured by the Konvex Tie Pad Co. of East St. Louis, Ill., were installed on August 27, 1958, in the south ½ of section 28 on the long 4½-deg curve south of East Bernstadt, replacing Western Felt Works wool felt pads. The Konvex pads were placed on 24 new creosoted oak ties using new 14-in double-shoulder tie plates and two cut spikes each for line and anchor (Fig. 5). These pads, $\frac{3}{16}$ in thick, exclusive of the coating, have a minimum of 5 plies, but may contain 6 or on occasion 8 plies. The manufacturer of the newly-developed coating expects that it will remain pliable in winter as well as summer and will provide a good seal with the tie.

Section 35

The north 30 alternate ties installed July 1950 were recoated on August 27, 1958, using Koppers' No. 16 tie sealing compound spread over the top surface only and covered with ¼-in stone chips, as shown in Fig. 6. The compound was applied at the rate of 1 gal for 2 ties. The subcommittee felt that recoating ½ the section should develop some data on the value of recoating part of the section for comparison with the ties not recoated.

In connection with the new sections, initial readings for information pertaining to tie abrasion, gage, alinement, etc., were obtained September 18 and 19, 1958.

Maintenance of Hold-Down Fastenings

From a detailed inspection of the hold-down fastenings by the AAR staff during the week of July 7, 1958, it was determined that a general retightening would not be justified. The maintenance which appeared desirable consisted of an out-of-face tightening and replacement of a limited number of missing or broken washers in sections 10, 14 and 22 of the pine tangent.

Section 10 with round-head cut spikes and single-coil washers had 47 percent loose washers and the last out-of-face retightening was in 1955. All of the anchor spikes were

removed and redriven with tie plugs in the same holes to determine if the fastenings would be more efficient in reducing plate cutting and resisting the uplift by the washers. Section 14 with two through bolts and single-coil washers had 21 percent loose, broken and missing washers. It was decided to retighten all bolts and replace the washers where needed. The last out-of-face maintenance was performed in May 1953. Section 22 with Oliver tie plate drive spikes and single-coil washers had 38 percent loose washers and all were tapped down. This spike has a little tendency to back out in the creosoted pine tie section.

Table 3 is a summary of the maintenance of all special hold-down fastenings since each section was installed. The tie plate lock spikes, Oliver hold-down drive spikes and Racor studs (except for finish driving with a pneumatic hammer) have required the least maintenance. The table on the maintenance of the hold-down fastenings and last year's report (Vol. 59, page 1035), showing their efficiency as to reducing plate cutting and gage widening on the curves, should be helpful in determining the most economical tie plate fastenings.

Gage of Test Curves

Gage of the test sections on the two 4½-deg curves is shown in Fig. 7. In general, the change in gage on two 4½-deg curves since 1957 has been very small. Sections 14 to 17, incl., continue to hold excellent gage since installation in 1947. Sections 10 to 13, incl., are somewhat more irregular, but the average change in the past year is negligible. Six-year-old sections 48 and 49 with Racor pads and/or studs have good uniformity and little change. Gage of the single-shoulder Erie tie plate sections 18 and 19 continues to be erratic, with section 19 showing greater change than the remainder of the curve.

On the short 4½-deg curve, section 26 with the DL&W diamond-bottom tie plate continues to show the best uniformity, but the average change since 1957 is about the same in all three sections. Section 21 and the north end of section 25 are giving less trouble with widening since they were regaged in 1956. Complete dieselization in 1956 has, no doubt, been helpful.

Fig. 8 shows the gage on the 5-deg curve at East Bernstadt. It will be noted that there were major changes in sections 40 and 41. This was influenced by the fact that changes in the crossing protection circuits were made and the insulated joints relocated after gage measurements were taken in 1957. Changes in other sections were small and do not appear significant at this time.

General Inspection

The subcommittee held its annual inspection of the test installations on May 21 and 22, 1958. Some of the visitors were escorted over the service tests in the afternoon of the first day by a member of the AAR research staff. T. G. Gill, chief, Seasoning and Preservation Section, Timber Engineering Company, and another member of the AAR staff, took the annual measurements on the two test sections having the Koppers' No. 16 sealing compound applied to the hardwood ties to reduce checking, splitting and weathering of the timber. Mr. Gill also served as the photographer on the second day.

Forty-five Track committee members and guests attended the inspection on the second morning when 21 tie plates were removed to examine the condition of the pads and other test materials, and the protection provided for the ties. The photographs included in Figs. 9 to 26, incl., have remarks in the captions calling attention to the details observed. The ⅛-in Dunne Rubber Company molded rubber pads in section 42

on the 5-deg curve have been worn thin and torn, and the ⅛-in J–M laminated asbestos-rubber pads in the north half of section 25 have been abraded severely at the field end of the outer rail plates in the short 4½-deg curve. It is judged that these pads should have a minimum thickness of $\frac{3}{16}$ in for a more satisfactory service life. Other pads of ⅛-in plus thickness—Racor fiber-rubber and ⅛-in Fabco fiber-rubber—have not been in these tests sufficiently long to pass on the adequacy of the thickness used. The AAR staff has recommended a minimum thickness of $\frac{3}{16}$ in, exclusive of the coating, to the suppliers that are in the process of developing an economical tie pad.

Tie Coatings

Sections 35 and 36 were established in July 1950 when Kopper's No. 16 sealing compound was applied to the top and ends of new and existing creosoted hardwood ties to investigate its capacity for retarding the splitting, checking and weathering of the timber. In section 35, which included 120 new ties, the coating was applied to all adzed surfaces before placing the ties and on top of the odd-numbered ties, leaving the even-numbered ties for controls. In addition, the ends of the coated ties in the south half of the section received an application of the coating. In section 36, consisting of 118 existing ties, the tops of all ties were coated and also the ends of the south 58 ties. All coated ties were sprinkled with ¼-in washed gravel for a protective covering. The test sections are located on fast tangent track laid with 131-lb rail, 6-hole joints and 13-in waffle-bottom tie plates. The weather at the time of the annual inspection on May 21, 1958, was mild with a temperature of 77 deg F. Information obtained regarding weather conditions indicated heavier than normal rainfall in early spring, but normal for a period just prior to the inspection. There was a light rain 36 hr before the inspection.

The efficiency index of the coating for keeping the splits covered was determined from the number of splits ⅛-in wide or larger on the top end faces of the ties. The efficiency factors for the new ties in section 35 were obtained from the following formula:

$$\text{Efficiency, percent} = 100 - \frac{\text{number of checks in coated ties}}{\text{number of checks in uncoated ties}} \times 100$$

Because all of the existing ties were coated in section 36, the original number of splits in the ties before being coated was used for computing the efficiency factors.

Values of the coverage efficiency of the coating for the eight-year test are tabulated below.

	Section 35—1950 Ties Percent							
Category	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*
All coated ties	75	74	76	52	52	53	58	39
Ties coated on top only	70	63	73	48	45	47	53	36
Ties coated on top and ends	79	85	80	55	60	60	63	42

	Section 36—Existing Ties Percent							
Category	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*
All coated ties	82	82	70	48	55	48	48	44
Ties coated on top only	64	75	61	36	44	40	43	38
Ties coated on top and ends	97	89	79	60	66	56	54	51

Attention is called to the sharp drop in efficiency factors of the coated ties in section 35 since 1957 which is the first appreciable change since the drop in 1954. There

is also a slight drop in these factors for coated ties in section 36. This reduction no doubt reflects to some degree the decrease of moisture content as indicated below.

A Delmhorst moisture detector was used to measure the moisture content of the top ¼ in of the ties to determine the effectiveness of the coating for retaining moisture in that portion of the tie. For the purpose of comparing coated existing ties in section 36 with uncoated ties, moisture readings were obtained from existing ties adjacent to the south end of the section.

	Section 35—1950 Ties			*Section 36—Existing Ties*		
Date	*Coated*	*Uncoated*	*Difference*	*Coated*	*Uncoated*	*Difference*
July 1951	16.5	10.2	6.3	...	...	...
June 1952	20.6	10.9	9.7	29.8	12.3	17.5
July 1953	18.5	11.8	6.7	24.7	11.5	13.2
July 1954	11.9	9.3	2.6	12.2	8.8	3.4
June 1955	13.1	11.5	1.6	14.0	11.6	2.4
June 1956	13.6	9.1	4.5	15.6	8.0	7.6
May 1957	16.9	11.3	5.6	18.5	9.3	9.2
May 1958	16.2	10.9	5.3	17.1	10.3	6.8

It will be noted that the average moisture content of the coated ties continues to be higher than for uncoated ties with the difference being slightly more in the existing ties than in the 1950 ties. In 1958, the moisture content of 1950 ties remained very close to 50 percent above that of uncoated ties, but for the existing ties, the differential dropped slightly although not enough to be significant.

For the past several years the coverage factors have indicated that better results were being obtained from the installation of new ties in section 35. The 1958 data, however, offset the previous trend and give an average coverage factor approximately equal to that of section 36 over the eight-year test period.

The only tie renewals made prior to the inspection of May 1958 were four reported for section 36 in 1957. While the coating was in generally fair condition, some has been abraded from the ties by frequent surfacing of the track which involves unloading and plowing off the ballast. Damage from that source has been greater on the existing ties than on the 1950 ties. There has also been normal deterioration in both sections.

Data from the 1950 ties will be evaluated by comparing tie life with that in other comparable AAR–L&N test sections, as in sections 2 and 9 with hardwood ties in tangent track.

Repeated Load Tests of Tie Pads, Etc.

Two tie wear testing machines, one of AAR design, Fig. 27, and one designed by Krouse Testing Machine, Inc., Fig. 28, are now on hand in the Engineering Laboratory at the Research Center, Chicago. Each machine is designed for a 20,000-lb tie plate load with horizontal forces on the rail alternating from 5000 lb inward to 10,000 lb outward of the track. In two to three weeks a test of five million loads can be completed. It is anticipated that these machines will develop valuable information in making accelerated tests of tie pads, hold-down fastenings, etc.

Economic Studies for the Use of Tie Pads, Etc.

Expenditures for future savings, such as for extending the service life of ties, etc., without increasing the cost of a tie year, or preferably at a reduction in the cost of a tie year, should be made on a conservative basis.

As an example, one southern road has the problem of using creosoted pine ties out-of-face in its main track where the joint ties had a service life of 17 years, com-

pared with 23 years for the intermediate ties. It is desired to increase the life of the joint ties but it is not practical to use hardwood ties. The road's records of tie renewals indicate that 70 percent of the joint ties were removed because of plate cutting. Only one tie pad will be required to extend the life of each joint tie from 17 to 23 years. At the same cost per year, without considering interest, the added cost per tie justified is $\frac{23-17}{17} = 35.3$ percent of the cost of a tie in place, estimated at $6.00.

From the graph shown in Fig. 29 by the dashed lines, only 22 percent added expenditure is justified to keep the annual cost, based on 4 percent compound interest, the same. Since only 70 percent of the joint ties fail from plate cutting, the added cost should be limited to $0.7 \times 22 = 15.4$ percent, or $0.154 \times \$6.00 = \$0.92$. This sum is adequate for purchasing a suitable tie pad plus a charge of $0.30 for labor applying the pad. The curves in the figure are based on the lower diagram on Manual page 3–4–3. A member of the Track Staff transposed the data in to the curves in Fig. 29 for rapid analysis of a given set of conditions.

Generally, a large proportion of the tie pads used by the railroads can be placed in connection with bridge tie renewals or relaying rail. This will eliminate the labor charge against the pads, except for a few cents for handling, etc. However, it is probable that when pads are replaced on the same ties the labor charge will require amortization. Consequently, except for expensive bridge ties or other special timbers, the second pad installation may not be economical. Therefore, in the test curves of the AAR–L&N tests, assuming present conditions of operation, the pads should protect the ties from plate cutting for at least 15 years.

General Remarks

While still in service, there are a number of tie pads which are no longer considered satisfactory or acceptable for use, as indicated below:

(a) The one-ply duck pad, section 3, has insufficient strength against tearing and ripping at the spikes and is deficient in protecting the tie from plate cutting.

(b) The 1948 Burkhart, $\frac{3}{16}$-in thick fiber pad, uncoated, in section 27, failed because of severe abrasion and some stretching.

(c) Western Felt Works, ¼-in wood felt pads, uncoated, in section 28, are badly worn, displaced and torn. The service life is too short and the pads are too expensive.

(d) Dayton Rubber Company's cast steel tie plates with raised rubber insert pads, sections 44 and 45, are not suitable because they concentrate the tie plate load on about ⅓ the area of a conventional tie plate and are prohibitive from a cost standpoint.

(e) Achuff sisal fiber pads, section 38. The impregnant became unstable in hot weather and the pads failed due to mashing, ripping, dislocation and disintegration.

(f) Johns–Manville rubber-vegetable pads, uncoated, section 39, had a high percentage with moderate splits at the anchor spikes and were superseded in 1950 by Johns–Manville rubber-composition pads with bottoms coated, which had major transverse splits and tears at the anchor spikes and did not remain sealed to the ties. Both pads have been superseded by J–M 1955 formulation of fiber-rubber pads as installed in section 55.

(g) The Taylor Fibre Company's rubber-vulcanized, uncoated, fiber laminated pads, section 40, failed due to the hard fiber layers splitting and becoming dislocated.

(h) The Dunne Rubber Company's ⅛-in molded rubber pad, section 42, has insufficient thickness and, because of pad abrasion, the service life will be too short.

(i) Johns–Manville ⅛-in laminated rubber-asbestos pads, uncoated, north 23 ties, section 25, are wearing thin account insufficient thickness.

The Fabco uncoated, pads, section 21, are showing major abrasion and tearing under the outside rail of the short 4½-deg curve. They are, however, still useful in protecting most of the ties from abrasion.

The Bird duck-burlap pads in sections 4 and 5, on the long 4½-deg curve are showing some delamination and dislocation, but are still effective against tie wear.

It has been shown that two types of pads ⅛-in. in thickness were too thin to give a satisfactory service life under the L&N operating conditions. Generally, with the exception of the ⅛-in plus Racor pad and the ⅛-in Fabco pads, roads having similar or more severe operating conditions will require $\frac{3}{16}$ in, or more, pad thickness for a good service life. Possibly roads with lighter traffic density and smaller average wheel loads than in the test track can obtain a satisfactory service life with some of the thinner tie pads. In these tests a satisfactory pad life should be a minimum of 15 years of protection from tie abrasion.

The ⅛-in Dunne Rubber Co. molded rubber pads in the 5-deg test curve appear to be failing from abrasion. Because this make of rubber pad has a tensile strength of only 600 psi in the transverse and longitudinal directions, possibly a pad made of rubber (not fiber-rubber) should have a minimum of 1000 psi. Practically all of the fiber-rubber pads tested in the laboratory had in excess of 1000 psi tensile strength in the longitudinal direction. Transversely, the fiber-rubber pads have a tensile strength of ¼ to ⅓ of the longitudinal value. On two occasions the tensile tests on fiber-rubber pads indicated they were cut wrong because the greater tensile strength was in the transverse direction.

The inspection of pads on the creosoted pine ties has emphasized, as heretofore, the advantage of using pads with good sealing qualities.

Last year's report included tie abrasion measurements and relative efficiency data of each type of tie plate fastening and this report contains a summary of the maintenance work. These two yardsticks should be of value in selecting a hold-down fastening that will meet the requirements on any particular railroad. The effective service life of the several hold-down fastenings has not been established. This factor can be estimated for the operating conditions prevailing where the spikes are to be used.

Acknowledgement

The Association is grateful to the L&N for its aid and cooperation in conducting the test and also to the supply companies for their interest and assistance.

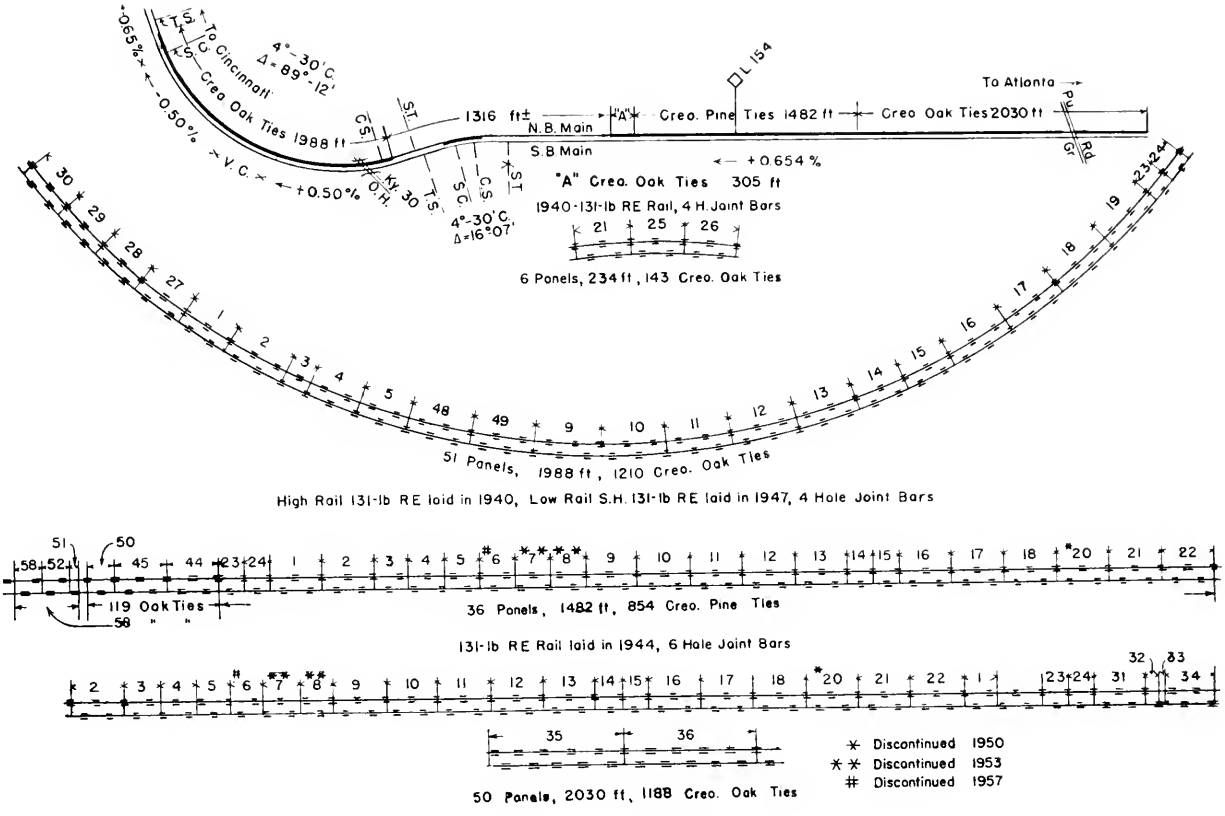


Fig. 1.- Plan of Test Track

TABLE 1. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties: Creo. Oak Curve	Creo. Oak Tang.	Pine Tang.	Total	Tie Plate Length in.	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb RE Rail)
1							Coatings and adhesives - no anchor spikes - subdivided as follows:
1.1	11	6	12	29	13	9-47	Beckosol No. 40. Hot paddle coat applied to bottom of tie plate
1.2	9	9	9	27	13	9-47	AREA Specification Waterproofing Asphalt applied as in subsection 1.1
1.3	0	4	6	10	13	9-47	CASCO Flexible Cement NT-442 applied to tie plate and tie in the field
1.4	3	3	6	12	13	9-47	NT-442 Cement applied to tie plate as a primer and CASCOPHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	9	27	13	9-47	Same as subsection 1.4 except the tie plates were cemented to the ties before creosoting
1.6	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating, designated No. 52
1.7	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating modified to further reduce flow, designated No. 53
1.8	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around brass screening, designated No. 54
1.9	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around 1/4 in mesh galvanized screening, designated No. 55
1.10	6	0	0	6	13	8-48	Solvated Sealz Coating. Heavy brush coat applied to tie and tie plate
2	59	47	48	154	13	8-47	No anchor spikes (Rubber line spike cushions were applied to the north 24 ties of each tangent section 12-49)
3	0	31	32	63	13	8-47	1-ply duck pad with asphalt coating (Made by Bird & Son), no anchor spikes
3	(b)24	0	0	24	13	6-52	Bird improved fiber-rubber pads (1-ply duck pads were in service on the same ties from 8-47 to 6-52)
4	(b)27	0	0	27	13	6-52	Bird vinyl pads on N. 27 ties (5-ply duck-felt pads were in service on the same ties from 8-47 to 6-52)
4	0	32	32	64	13	8-47	5-ply Bird duck-felt pads, no anchor spikes
4	20	0	0	20	13	8-48	5-ply Bird duck-burlap pads on the south 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	20	0	0	20	13	8-48	7-ply Bird duck-burlap pads on the north 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	29	31	32	92	13	8-47	7-ply Bird duck-felt pads, no anchor spikes
6*	0	32	32	64	13	8-47	2 each of cut spikes for line and Racor Studs for anchors, (Changed from 2 Racor Drive Tight line spikes 12-49)
7*	0	32	32	64	13	8-47	2 each of Racor Drive Tight (Sandberg) line and anchor spikes. (Anchor spikes replaced 11-48)
8*	0	31	32	63	13	8-47	2 each of cut spikes for line and Racor Drive Tight (Sandberg) for anchors. (Anchor spikes replaced 11-48)
9	59	48	48	155	13	8-47	2 each of cut spikes for line and anchors. (Rubber anchor spike cushions were applied to the north 10 pine ties 12-49)
10	59	47	49	155	13	8-47	2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153	13	8-47	2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153	13	8-47	2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2	13	8-47	2 cut spikes for line and 2 cone neck Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141	13	8-47	2 cut spikes for line and 2 Elastic Spikes of design No. 93 for anchors
13	12	0	0	12	13	8-47	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors (North 12 ties)
14	47	24	24	95	13	8-47	2 cut spikes for line and 2 - 3/4 in thru bolts with single coil washers for anchors — Applied in the field
15	48	24	24	96	13	9-47	2 cut spikes for line and 2 - 3/4 in thru bolts with single coil washers for anchors — Applied in shop under load
16(a)	60	47	48	155	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers for anchors
17	60	47	47	154	13	8-47	2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve (PRR standard 14-3/4 in tie plates cut to a 13-in. length with 1/4 in eccentricity)
18	58	48	48	154	13	8-47	No anchor spikes. Erie single shoulder tie plate with diamond bottom and zero eccentricity
19(a)	59	0	0	59	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers and above Erie RR tie plate
21	0	47	47	94	13	8-47	Fabco tie pads, 1/4 in thick, uncoated, no anchor spikes
21	47	0	0	47	13	8-48	Fabco tie pads, 1/4 in. thick, uncoated, no anchor spikes

(Continued on next page)

TABLE 1. (CONCL.) DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties				Tie Plate Length in	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb RE Rail)
	Creo. Oak		Pine				
	Curve	Tang.	Tang.	Total			
22	0	48	48	96	13	8-47	2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil spring washers for anchors
23	24	24	23	71	14	9-47	L.& N. standard construction with 2 each of cut spikes for line and anchors
24	24	24	24	72	14	9-47	Same as section 23, except a Rails Co. compression clip was applied to alternate tie plates
25	47	0	0	47	13	8-48	Johns-Manville, uncoated, laminated rubber-asbestos tie pads; 1/8 in thick in north panel, 1/4 in thick in south panel, no anchor spikes
26	49	0	0	49	13	8-48	D&W D.S. diamond bottom tie plate with 1/2 in eccentricity, 2 cut spikes for line and 1 anchor only
27	48	0	0	48	SH 13	10-48	Burkart fiber pads, no anchor spikes
28	24	0	0	24	SH 13	9-49	Western Felt Works wool felt pads, 1/4 in thick, no anchor spikes (North 24 ties)
28	24	0	0	24	14	6-48	Konvex Tie Pad Co. 3/16 in tire carcass pads coated top and bottom, 2 cut spikes each line and anchor (South 24 ties)
29	48	0	0	48	SH 13	9-49	Bird fiber-rubber pads, 1/4 in thick, coated, no anchor spikes
30	48	0	0	48	SH 11	9-49	Bird 5-ply duck-burlap pads. SH 11 in plates were cut from 13 in Plan 58 plates, no anchor spikes
31	0	48	0	48	14	8-49	G&H Controls No-Creep rail anchors on alternate tie plates. 2 cut line spikes on unanchored ties, 1 cut line spike and 2 Oliver Tie Plate Drive Spikes for anchors on anchored ties
32	0	12	0	12	14	9-49	Farbertite. Paddle coat applied to adzed surface and bottom of tie plate, no anchor spikes
33	0	5	0	5	14	9-49	Tie plates cemented to ties as in section 1.5 but under ideal conditions, no anchor spikes
34	0	48	0	48	14	9-49	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors. Asphalt roofing paint brushed on adzed surfaces of south 24 ties
35	0	120	0	120	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on alternate new ties, 2 each of cut line and anchor spikes
36	0	118	0	118	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on existing ties, 2 each of cut line and anchor spikes
44	0	48	0	48	12 7/16	11-50	Dayton Rubber Co's. cast steel tie plates with raised rubber insert pads on new ties, 2 each of cut line and anchor spikes
45	0	47	0	47	12 7/16	11-50	Same as section 44 except that existing ties in track were used
48	58	0	0	58	14	8-52	Racor coated tie pads with 2 cut line spikes and 2 Racor studs for anchors
49	60	0	0	60	14	8-52	2 cut spikes for line. 3 Racor studs as anchors on N. 30 ties and 4 on S. 30 ties
50	0	24	0	24	14	7-53	Paddle coat of "Anker Seel" applied to adzed surfaces, 2 each of cut line and anchor spikes
51	0	10	0	10	14	7-53	2 cut spikes for line and 2 creo. hard wood Nordberg pegs for anchors
52	0	24	0	24	14	8-53	Paddle coat of Protek-Tie applied to adzed surfaces, 2 each of cut line and anchor spikes
58	0	24	0	24	9	8-58	Railroad Rubber Products double shoulder 7 in x 9 in rubber tie plates, 4 cut spikes for line
	1,353	1,365	854	3,572			Totals

Notes: All of the new 13-in tie plates, except as noted above, were of the AREA Plan 58 (Modified) design with flat rail seat. Second hand (SH) 13-in tie plates were of the Plan 58 design with rolled circular crown. All of the 14-in tie plates placed prior to 1949 were of the AREA Plan 68 design and subsequent installations were of the current design, AREA Plan 14. All tie plates have flat bottom except as noted above.
In the sections on the two 4-deg 30 min curves where no anchor spikes were provided, 4 cut spikes were used.
(a). In the north half of each portion of the test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used. Prior to 1952, all of the above tie pads were placed without anchor spikes, except in sections 44 and 45. (b). These pads have 2 each of cut line and anchor spikes.
Section 20 with 2 Thompson rail and tie plate clamps has been excluded from this table and discontinued upon request by the sponsor.
Each portion of each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.
*The supplier of the special hold-down fastenings in sections 7 and 8 requested discontinuance of these installations in 1953.
**The supplier of the special hold-down fastenings in section 6 requested discontinuance of these installations in 1957 because the Racor Studs are of obsolete design.
Konvex pads on the south 24 ties of section 28 installed Aug. 27, 1958 replaced Western Felt Works wool Felt pads installed Sept. 1949.
North 30 alternate new ties section 35 recoated with Koppers Tie Sealing Compound with covering of 1/4 in stone chips Aug. 27, 1958.

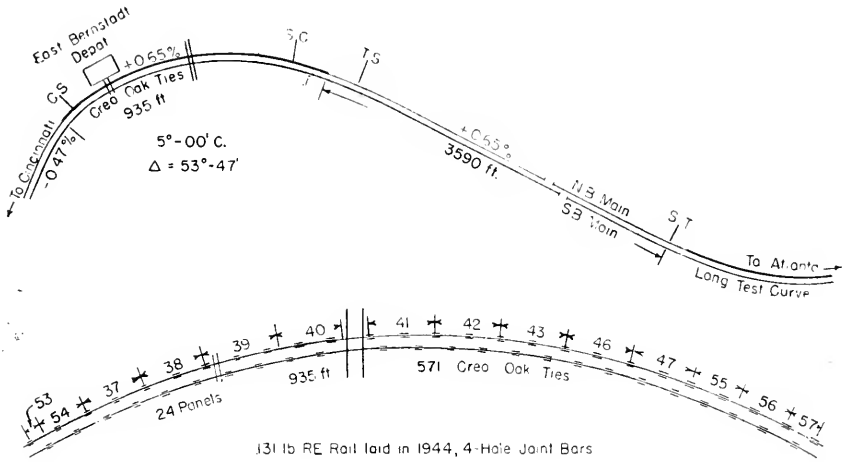


Fig. 2.– Plan of Test Track

TABLE 2. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 2.

Section No.	No. of Creo. Oak Ties	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pad AREA Flat Bottom 14-in Tie Plates, 131-lb RE Rail
37	48	7-50	2 each of cut spikes for line and anchors
38	48	8-58	Bird 5-ply coated pads (on new ties) with 2 Bernuth, Lembeke Gage Lock Spikes for line and 2 Bernuth, Lembcke Tie Plate Lock Spikes for anchor (North 24 ties LD jute pads) (South 24 ties SD duck and burlap pads)
39	22	7-50	Johns-Manville rubber-vegetable and asbestos fiber pads, uncoated (North 22 ties)
39	22	11-51	Johns-Manville rubber-comp. pads with coating on the bottom side, replacing original J. M. pads placed 7-50
40	24	7-50	Taylor Fibre Company's rubber-vulcanized fiber laminated pads (North 24 ties)
40	24	5-56	Bird 5-ply LD pads (Jute), coated (on 1950 ties)
41	23	7-50	Fabco pads, uncoated (North 23 ties)
41	12	7-51	Fabco pads with an oxidized asphalt coating compound on the bottom side. (These pads replaced pads placed in 7-50 with Baker's K-2 cement on the bottom side)
41	12	7-50	Fabco pads coated on both sides with Baker's S-72 cement (South 12 ties)
42	48	7-50	Dunne Rubber Company's molded rubber pad, 1/8-in thick uncoated
43	47	7-50	2 each of cut spikes for line and Racor Studs for anchors
46	24	11-51	Racor rubber-fiber pad, uncoated
46	25	11-51	Racor rubber-fiber pad with asphaltic coating on both sides
47	48	6-52	Burkart fiber pads, coated on bottom side
53	13	6-55	Nox-Rust tie seals under tie plates (solid sheet of Protek-Tie, approximately 1/8-in thick)
54	36	6-55	Railroad Rubber Products natural rubber pads 1/4-in thick, uncoated. The adzed surfaces of the south 10 ties were coated with Super Seal, a liquid rubber sealant
55	35	6-55	Johns-Manville fiber-rubber pads, 1/4-in thick, bottom coated
56	36	6-55	Fabco pads, bottom coated, 1/4-in thick on north 18 ties and 1/8-in thick on south 18 ties
57	24	6-56	2 each of cut spikes for line and Spring Lags for anchors
	571		Total

Notes: All pad sections have 2 each of cut line and anchor spikes. All sections, except Nos. 46 and 47, were installed with new AREA Plan 12 tie plates. Sections 46 and 47 have SH 14-in AREA Plan 6B tie plates. Plan 6B was withdrawn from the Manual in 1948.
Each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.

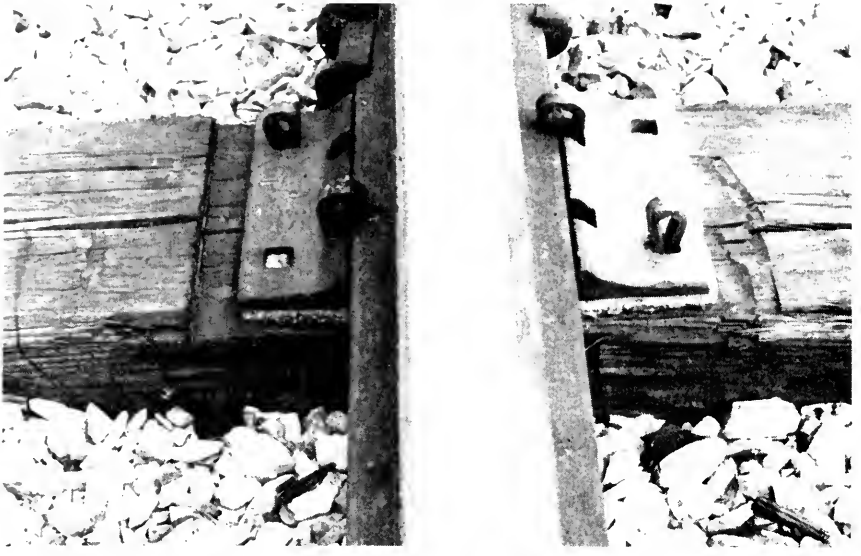


Fig. 3—Section 04, Bird 5-ply tie pads, coated, and two each of gage lock spikes and tie plate anchor lock spikes in three panels of existing ties, 13-in tie plates in 5-deg 36-min test curve. This construction is the same as that installed in Section 38 in the 5-deg test curve except for new ties and 14-in tie plates.

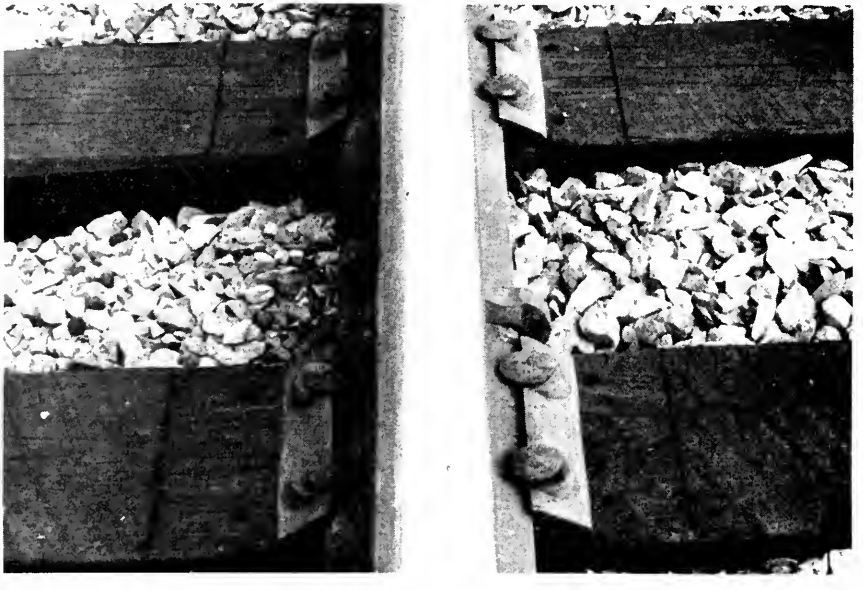


Fig. 4—Section 58, double-shoulder rubber tie plates (7 by 9¼ in) installed in one panel of new creosoted oak ties in tangent track.

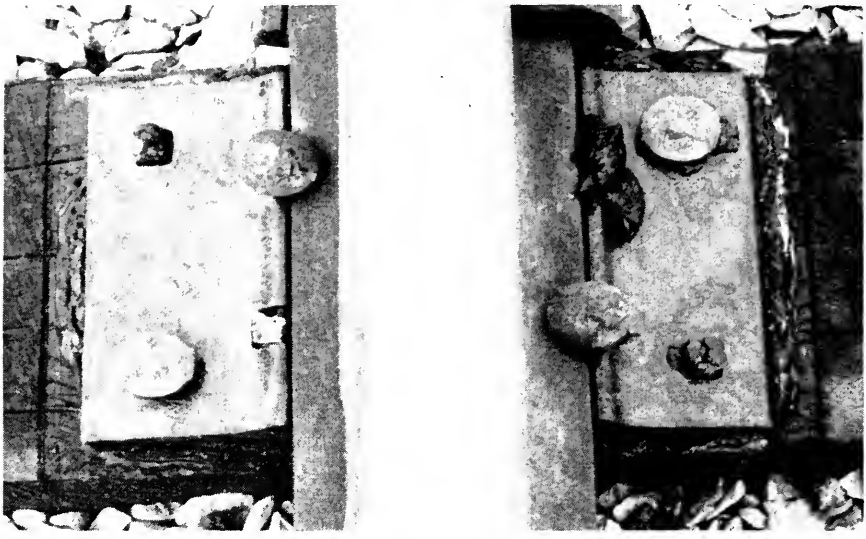


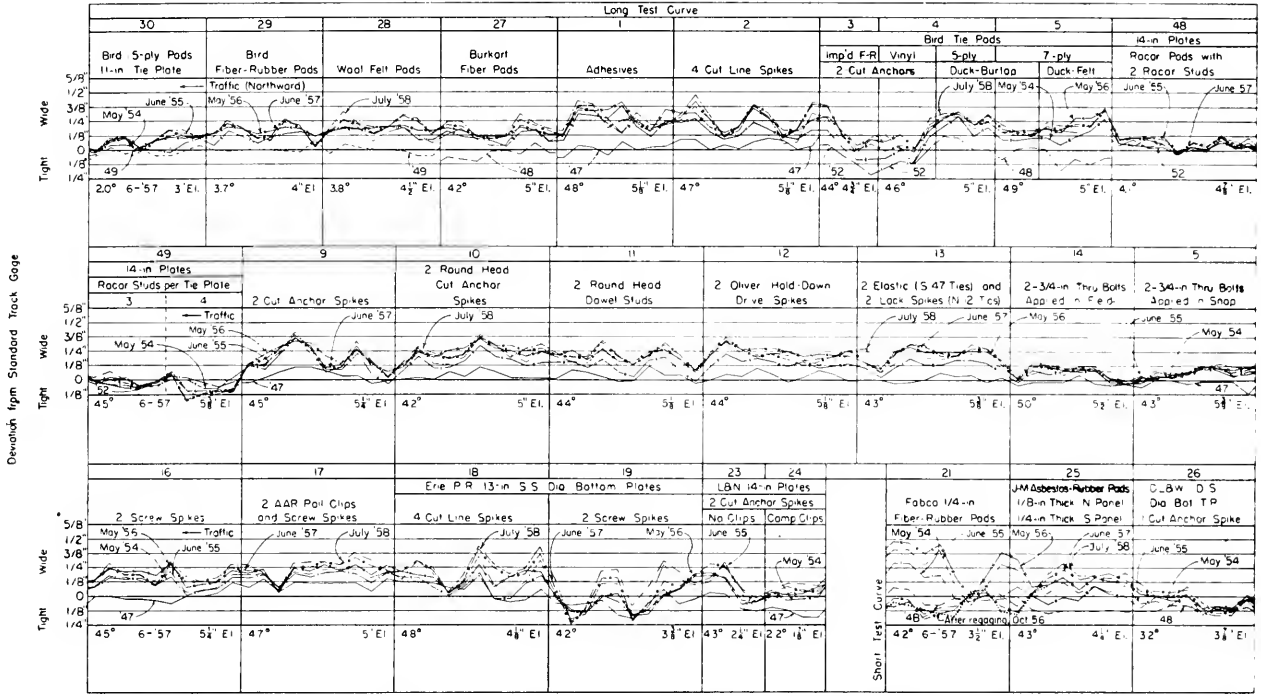
Fig. 5—South half of Section 28, 3/16-in double-coated tire-carcass tie pads, 14-in tie plates, new creosoted oak ties in the long 4½-deg curve. In three weeks the stabilized rubber coating had filled the plate holes well.

Fig. 6—Section 35, view of 1950 ties after the 30 alternate coated hardwood ties in the north half of the section had been recoated first time with Koppers' No. 16 Sealing Compound in tangent track.

TABLE 3. SUMMARY OF SPECIAL HOLD-DOWN FASTENINGS TAPPED DOWN OR RETIGHTENED FROM THE DATE OF INSTALLATION THROUGH SEPTEMBER 1958 ON THE L&N RR., NEAR LONDON, KY.

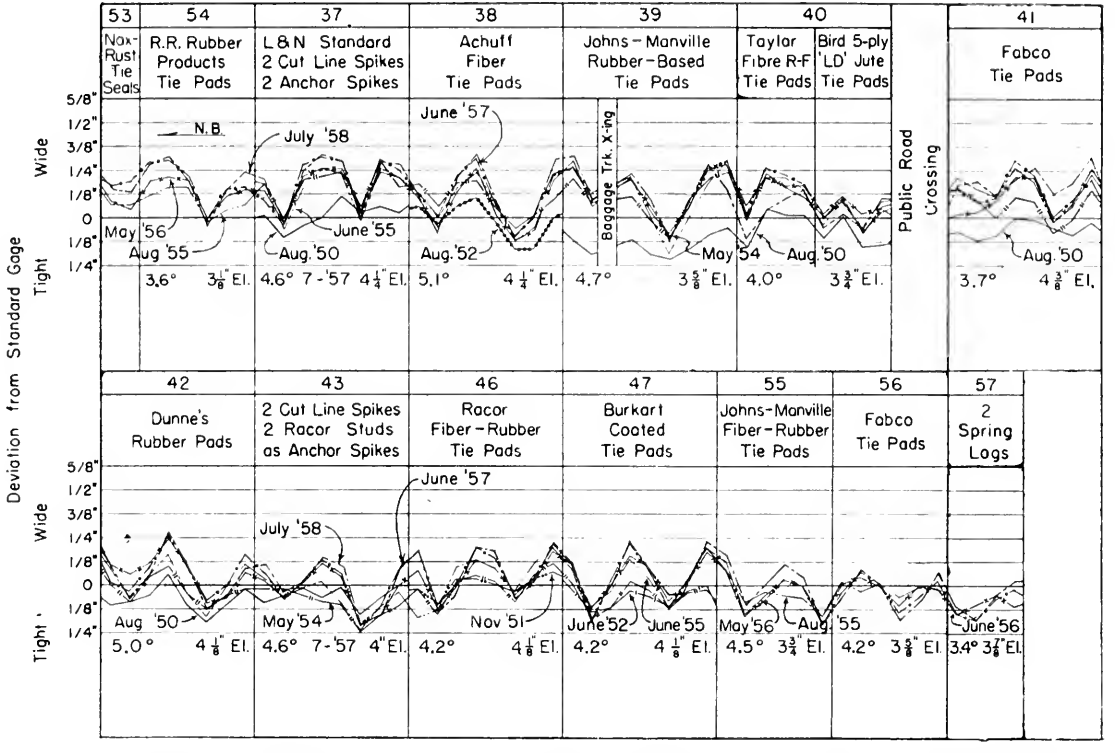
Sec. No.	Hold-Down Fastenings	Date Built	Long 4°-30' Curve		Tangent Creo. Oak Ties		Tangent Creo. Pine Ties		Total For Each Construction	
			(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
10	2-Round Head cut spikes with single-coil spring washers	8-47	180	80	74	39	588	300	842	39
11	2-Round Head Dowel studs with double-coil helical spring washers	8-47	95	40	2	1	230	122	327	54
12	2-Oliver hold-down drive spikes with double-coil helical spring washers	8-47	0	0	0	0	56	29	56	9
13	2-Elastic spikes, design No. 93	8-47	2	1	0	0	108	129	110	65
13	2-Tie plate lock spikes (North 12 Ties)	8-47	0	0	-	-	-	-	0	0
14	2-Thru bolts with single-coil spring washers (field)	8-47	188	100	96	100	184	211	468	137
15	2-Thru bolts with single-coil spring washers (shop)	8-47	192	100	96	100	86	110	374	102
16	2-Screw spikes with double-coil spring washers	8-47	248	103	4	2	220	115	472	76
17	2-AAR spring rail clips and screw spikes	8-47	258	116	354	233	236	137	848	161
19	2-Screw spikes and double-coil spring washers with 13 in Erie RR. diamond bottom tie plates	8-47	254	108	-	-	-	-	254	108
22	2-Oliver tie plate drive spikes with single-coil spring washers	8-47	-	-	72	38	438	230	510	134
31	G2H Controls No-Creep rail anchors and 2-Oliver tie plate drive spikes without spring washers on anchored ties only, 14-in tie plates	8-49	-	-	96	100	-	-	96	100
34	Tie plate lock spikes - Asphalt coating, 14 in tie plates	9-49	-	-	0	0	-	-	0	0
48	2-Racor studs - Racor tie pads, 14 in tie plates	8-52	0	0	-	-	-	-	0	0
19	2-Cut line spikes, 3 Racor studs, 14 in tie plates	8-52	0	0	-	-	-	-	0	0
49	2-Cut line spikes, 4 Racor studs, 14 in tie plates	8-52	0	0	-	-	-	-	0	0
			5° Curve							
13	2-Racor studs, 14 in tie plates	7-50	188	(a)100	-	-	-	-	188	100
57	2-Cut line spikes, 2 spring lags, 14 in tie plates	6-56	0	0	-	-	-	-	0	0

Notes Col. (1) Number of hold-down fastenings retightened or tapped down. Col. (2) Percentage of hold-down fastenings retightened or tapped down. All tie plates have a flat bottom and 13-in length, except as indicated above. (a) Racor studs in section 43 were tapped down with an air hammer in July 1951, because they were not driven home when originally applied with a maul. All maintenance work on the special hold-down fastenings, except the Racor studs, was performed manually. The work of retightening the special hold-down fastenings has required 121 man-hours. In addition, 35 man-hours were required for applying No-Ox-Id "A" Special twice to the dowel studs in section 11 and the thru bolts in sections 14 and 15 to protect the exposed threads from corrosion. For more details of this work, see AREA Proceedings Vol. 53, 1952, page 792; Vol. 54, 1953, page 1057; Vol. 55, 1954, page 728; Vol. 56, 1955, page 842; Vol. 57, 1956, pages 713-715; Vol. 59, 1958, page 1055 and Maintenance this report. Section 6, previously reported, was discontinued in 1957 at the request of the supplier.



Notes All test sections have 13-in tie plates, except as noted above. All tie plates have a flat bottom, except as indicated otherwise. Where no anchor spikes are indicated above, four cut line spikes per plate were provided. Sections with anchor spikes have two cut line spikes. The oldest gage record shown for each section represents the condition at the beginning of the original test or when a section was revised by changing the tie pads or fastenings. The following sections were regaged: Sections 4 and 5, Aug 1948, North portion Section 16 by relaying outer rail, Sept 1953, Section 21, Sept 1953. Two cut anchor spikes were added to the south 24 plates in the outer rail of Section 21, Nov 1953. All ties were installed as of the earliest date shown, except in Sections 3, 4 and 5, the 1947 ties were retained in service. Two cut anchor spikes were added to the north 23 plates in the outer rail of Section 21 after regaging, Oct 1956.

Fig. 7. Gage, Curvature and Elevation of Each Section of Test Track on the 4°-30' Curves, Mile L-154, L&N RR, near London, Ky



All sections have new AREA 14-in Plan 12 flat bottom tie plates, except sections 46 and 47, which have second hand AREA Plan 6B flat bottom tie plates. All sections have two each of cut spikes for line and anchor, except as noted.
----- After replacing pads in 1952

Fig 8 Gage, Curvature and Elevation of Each Section of Test Track on the 5-deg Curve, Mile L-153, L & N RR, at East Bernstadt, Ky.

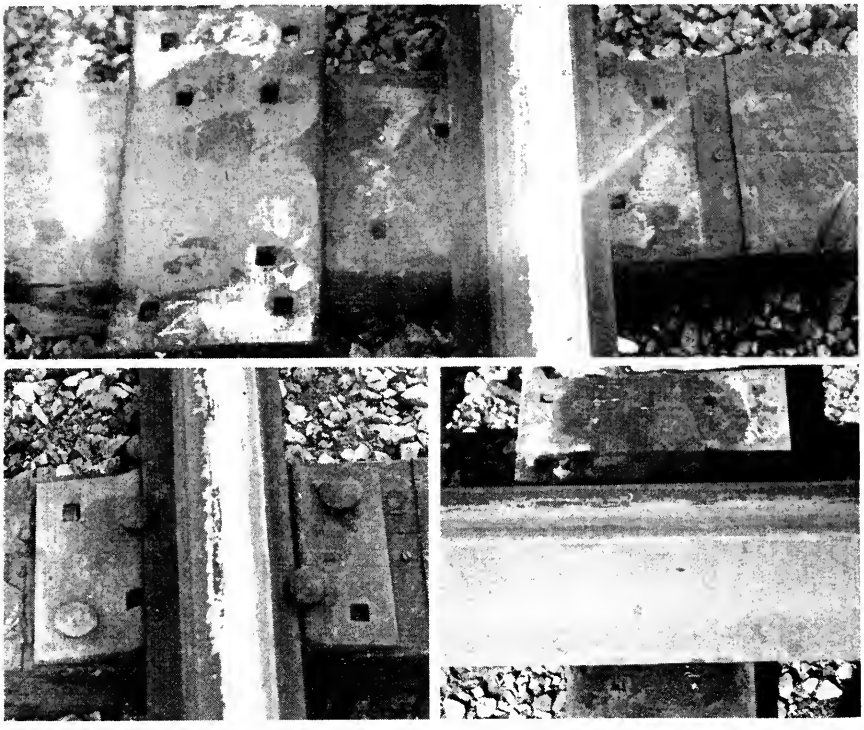


Fig. 9—Section 53, Nox-Rust tie seal under tie plate, 35 months of service, inner rail 5-deg curve. This material did not seal all of the vacant tie plate holes. Approximately ¾ of the underplate area showed the dark color of the seal. This tie plate had taken a good seat and there was little sand under it. The 1957 report indicated the excess tie wear in the inner rail was only 11 percent.

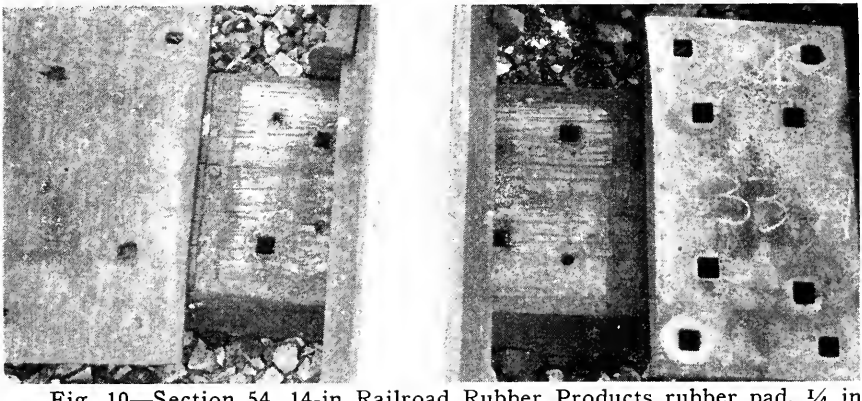


Fig. 10—Section 54, 14-in Railroad Rubber Products rubber pad, ¼ in thick, uncoated, with adzed surface coated with a liquid rubber sealant, 35 months of service, inner rail 5-deg curve. Some sand was under the pad, all sealant was gone except outside the pad area. Pad condition was good but the sealant was of little value.

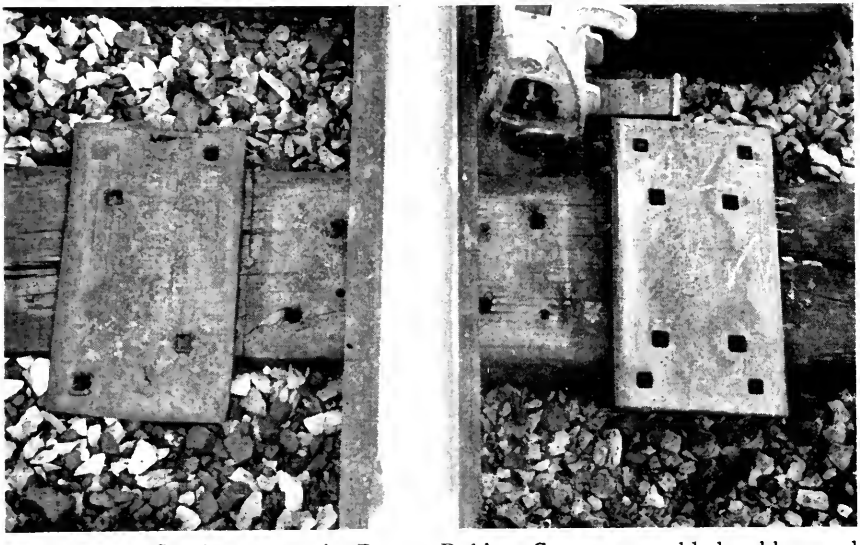


Fig. 11—Section 42, 14-in Dunne Rubber Company molded rubber pad ⅛ in thick, uncoated, 94 months of service, inner rail 5-deg curve. More than a normal amount of sand was under the pad. Some compression of the wood was observed and the adzed surface was damp under the pad. The pad was worn very thin and was torn at two locations. The thickness of ⅛ in is deemed inadequate for protecting ties over a satisfactory service life. The shallow grooves in both sides of the pads may have been a factor in the deterioration of the material.

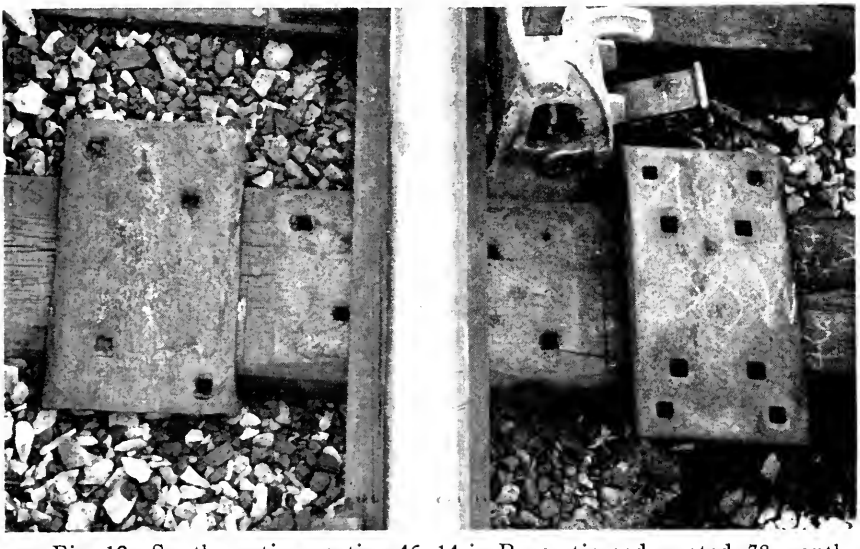


Fig. 12—South portion section 46, 14-in Racor tie pad, coated, 78 months of service, inner rail 5-deg curve. There was a little sand under the pad and slight wood compression was observed. The pad condition was good but it was not sealed to the tie.

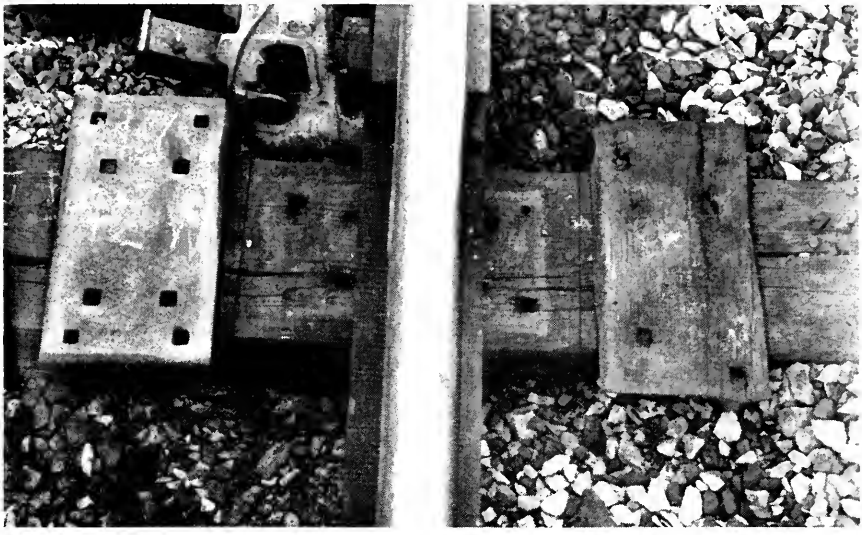


Fig. 13—Section 47, 14-in (1952) Burkart fiber pad, coated, 71 months of service, inner rail 5-deg curve. The pads had stretched some lengthwise and the spike holes had elongated. Some sand and free water were found under the pad. Pad condition was fair.

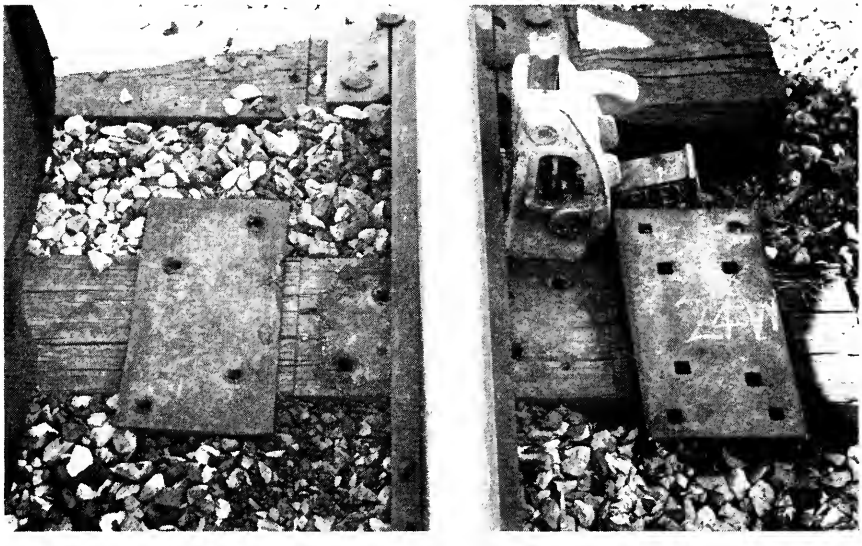


Fig. 14—Section 55, 14-in Johns–Manville fiber-rubber pad, ¼ in thick, coated 35 months of service inner rail 5-deg curve. Pad was not sealed to the tie but the underpad area was clean except for a little sand at the gage end. About ¾ of the coating had adhered to the adzed surface and partly filled some of the splits in the tie. Pad was in good condition.

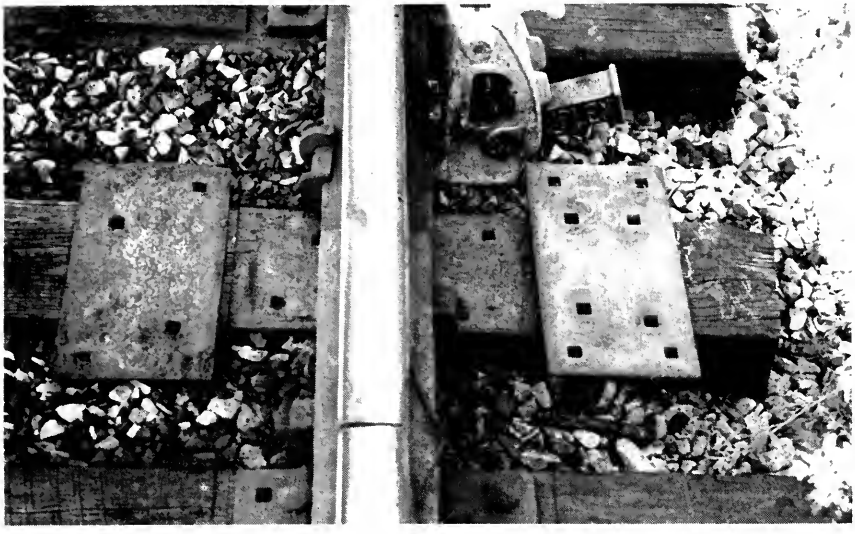


Fig. 15—South portion section 56, 14-in Fabco fiber-rubber pad, 1/8 in thick, coated, 35 months of service, inner rail 5-deg curve. Pad was in good condition. It was sealed for about 7/8 of its area and had a strong bond only on the gage end.

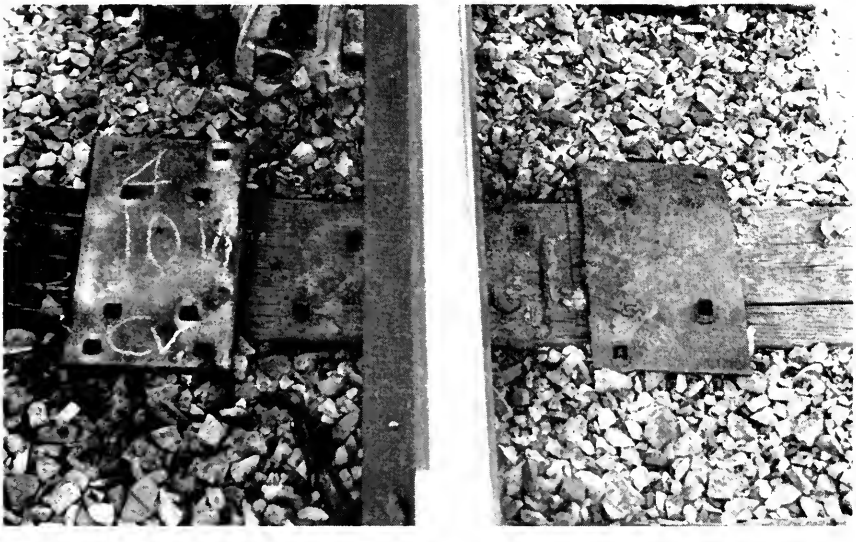


Fig. 16—North portion section 4, 13-in Bird Vinyl pad, coated, 71 months of service, outer rail long 4½-deg curve. Pad had a good seal for 2/3 of its area and was in good condition. The 1957 tie wear measurements in control Section 2 indicated 22 percent greater wear on the outer rail than on the inner rail.

Fig. 17—South portion Section 4, 13-in Bird 5-ply duck-burlap pad, coated, 117 months of service, outer rail, long 4½-deg curve. Pad had a strong seal for about ⅞ of its area. There was a little compression of the wood. Pad condition was satisfactory.

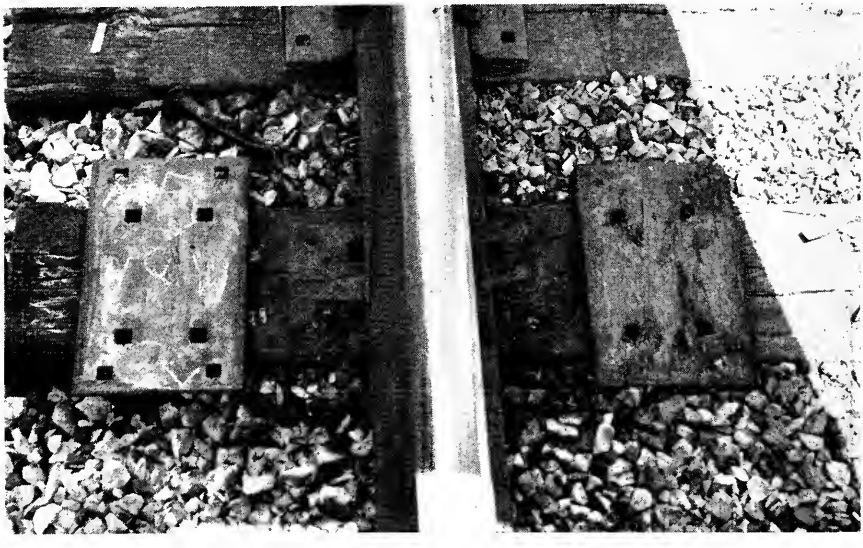


Fig. 18—North portion Section 5, 13-in Bird 7-ply duck-burlap pad, coated, 117 months of service, outer rail, long 4½-deg curve. This pad had a good seal and was in good condition. Two other pads were inspected where the tie plates had been bent by one derailed truck, July 1952, and were not sealed to the tie.

Fig. 19—South portion Section 5, 13-in Bird 7-ply duck-felt pad, coated, 129 months of service, outer rail, long 4½-deg curve. This pad was ⅞ sealed and was in better condition than the average. There was a little sand at the field end and slight wood compression. Some of these pads are badly delaminated and dislocated.

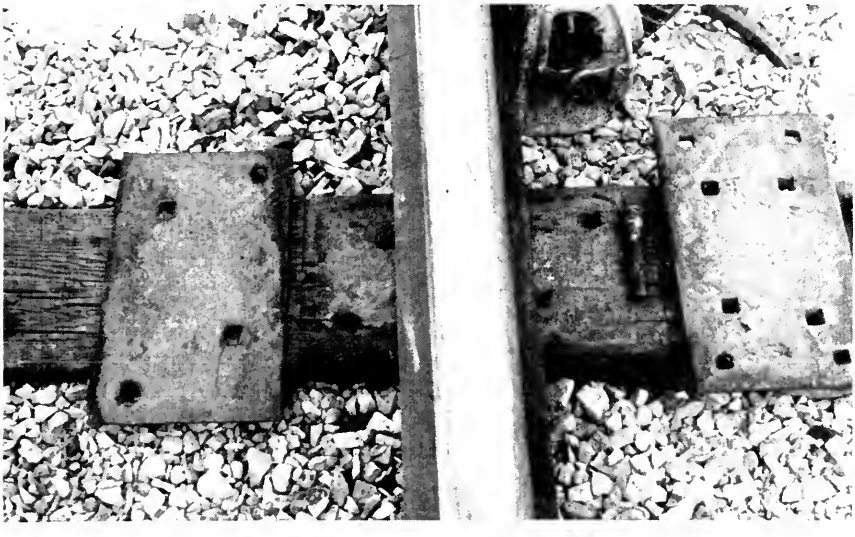


Fig. 20—Section 48, 14-in Racor fiber-rubber tie pad, coated, two Racor studs, 69 months of service, inner rail long 4½-deg curve. Pad had a fair seal with a little sand at the gage end. The pad coating covered about ⅞ of the underpad area. The pad was in good condition.

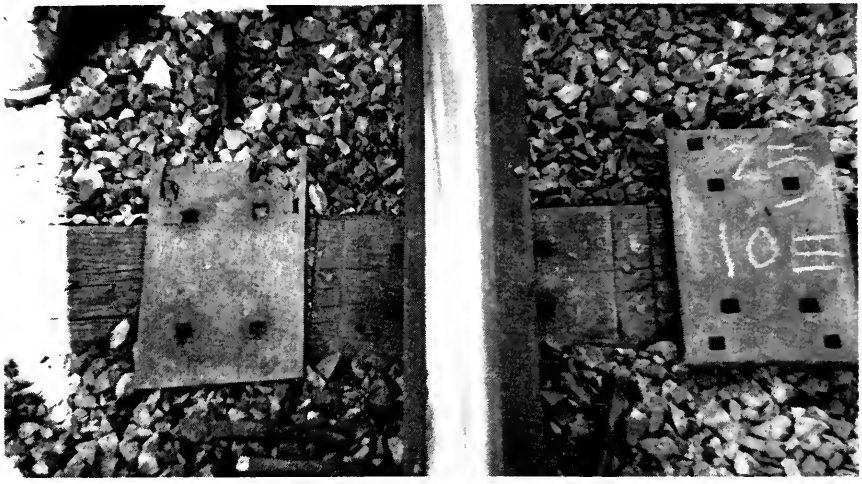


Fig. 21—North portion Section 25, 13-in Johns–Manville laminated rubber-asbestos pad, ⅛ in thick, uncoated, 117 months of service, outer rail, short 4½-deg curve. This pad had abraded the tie at the field end almost ⅛ in. The field end of the pad was abraded to a feather edge. These pads, as expected, are failing because of abrasion. The ⅛ in thickness is inadequate for a good service life.

Fig. 22—Section 50, paddle coat of "Anker Seel" applied to the adzed surface of oak ties, 14-in tie plates with four cut spikes, 58 months of service, tangent track. Note that the "smear" is still in the four vacant plate holes. Obviously there was no seal to the tie. The underplate area was reasonably free from sand, etc. This smear has performed better than the others tested. However, when the smear is effective it keeps out sand and water, which are accelerators to tie abrasion.

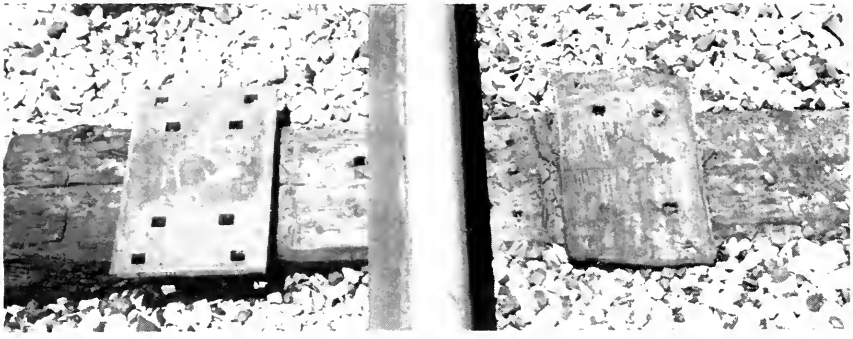


Fig. 23—Section 4, 13-in Bird 5-ply duck-felt pad, coated, 129 months of service, creosoted pine ties, tangent track. The pad has no bond with the adzed surface but the underplate area was clean. There was about 1/16-in compression of the wood at the gage end of the plate. The pad had some damage from delamination and was in better condition than the average of this section.

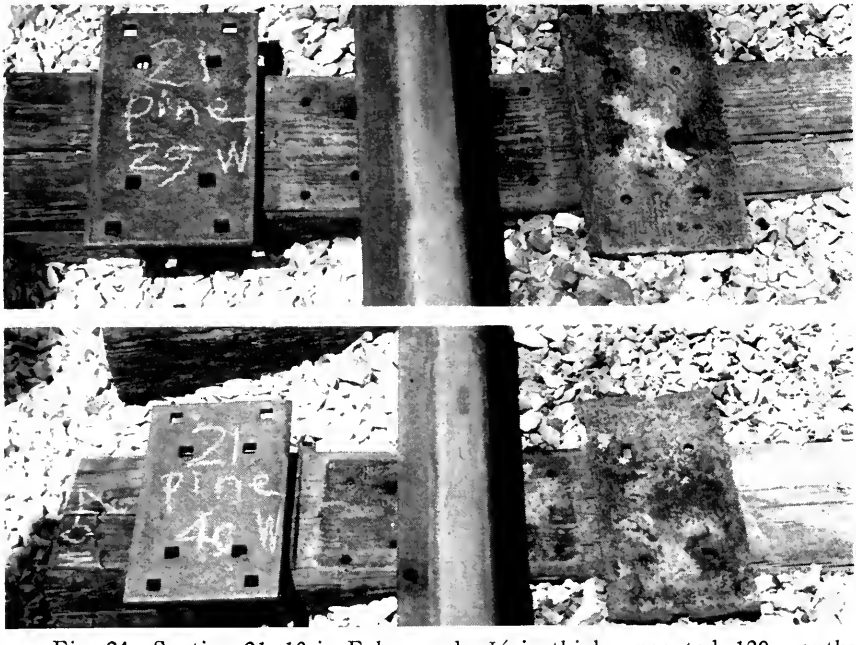


Fig. 24—Section 21, 13-in Fabco pads, ¼ in thick, uncoated, 129 months of service, creosoted pine ties, tangent track. In the upper view there was free water on the adzed surface and much sand on the bottom of the pad. Abrasion and compression of the wood were moderate. The pad was in moderately good condition. The lower view shows the second pad removed. The wood under the pad was wetter than in the upper view and the wood compression and abrasion was twice as deep as found under the Bird pad in Fig. 23. The pad in the lower view was stretched and abraded some. The above comparison of the Bird tie pad and the second Fabco pad demonstrates the advantage of having sealed pads on softwood ties.

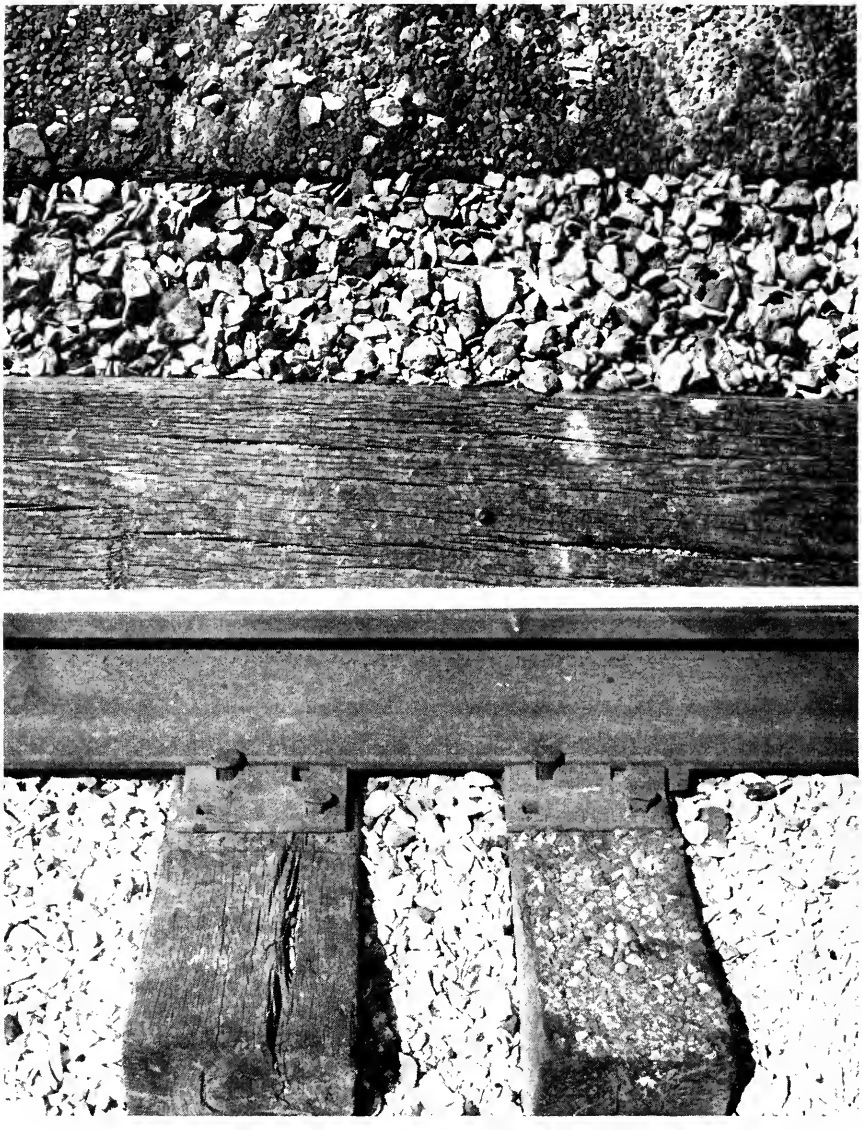


Fig. 25—Section 35, 1950 creosoted oak ties coated with Koppers No. 16 sealing compound with a covering of ¼-in washed gravel, 94 months of service, tangent track. Top view—top of ties 58 and 57 (even numbered ties were left uncoated for controls) between the rails. Bottom view—west ends of ties 46 and 47. Before placing the tie, a paddle coat of the sealing compound was applied to all adzed surfaces. Tie plate 19W was removed for inspection (no picture). The 13-in waffle-bottom tie plate had trapped the compound under it and the underplate area was clean and partly covered by the coating. The 1957 tie wear measurements in this section indicated for 120.1 million gross tons of traffic a reduction of 24 percent below that of control Section 2 with oak ties and 13-in flat-bottom tie plates.

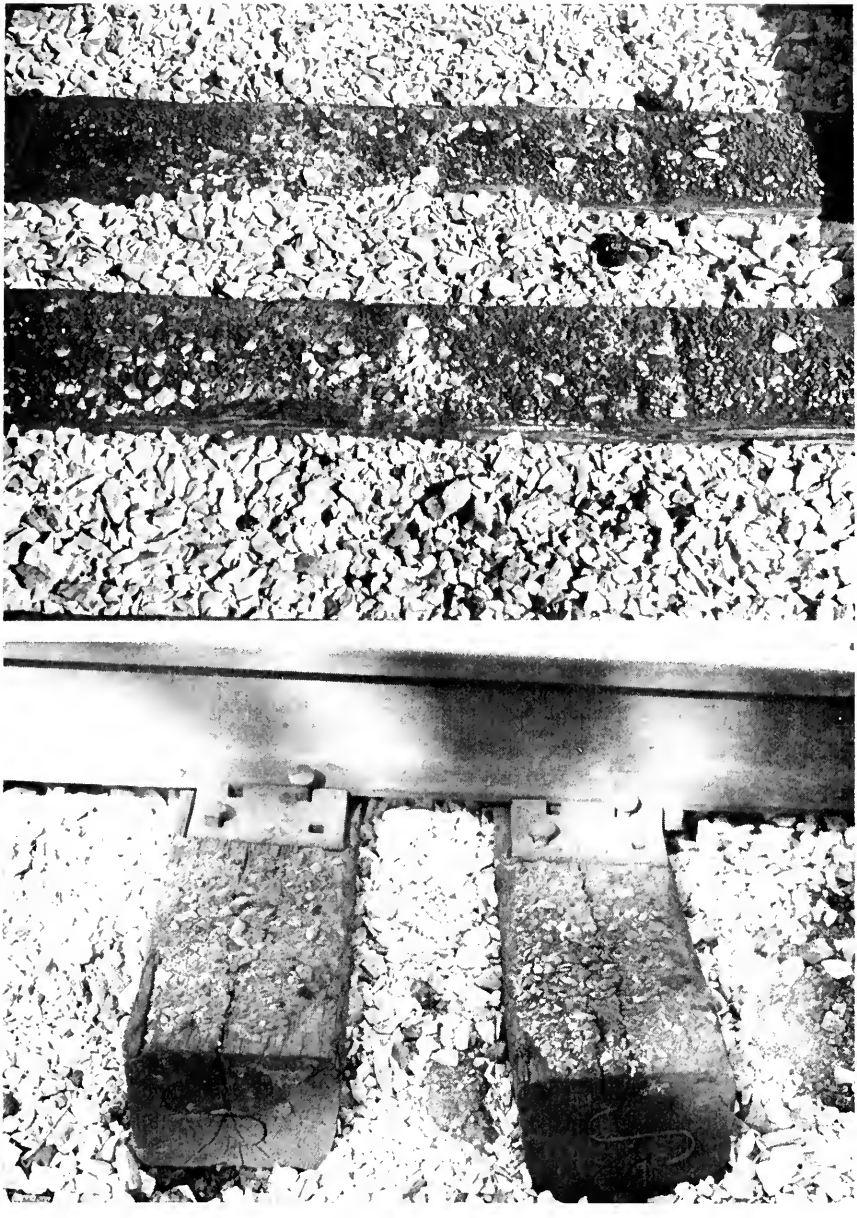


Fig. 26—Section 36, Koppers No. 16 sealing compound applied to existing creosoted hardwood ties in 1950, 94 months of service, tangent track. Top view—top of ties 2 and 3 between rails. Bottom view—west end of ties 30 and 31.

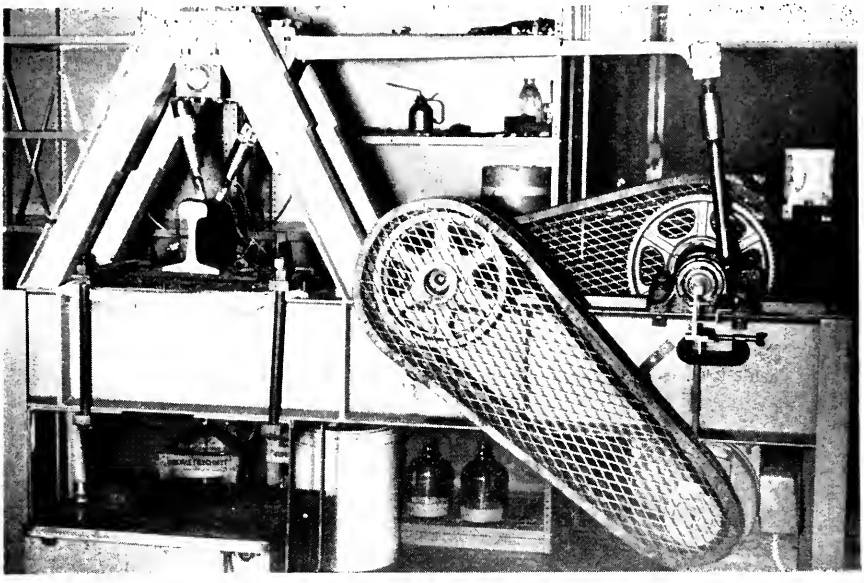


Fig. 27—AAR design tie wear testing machine.

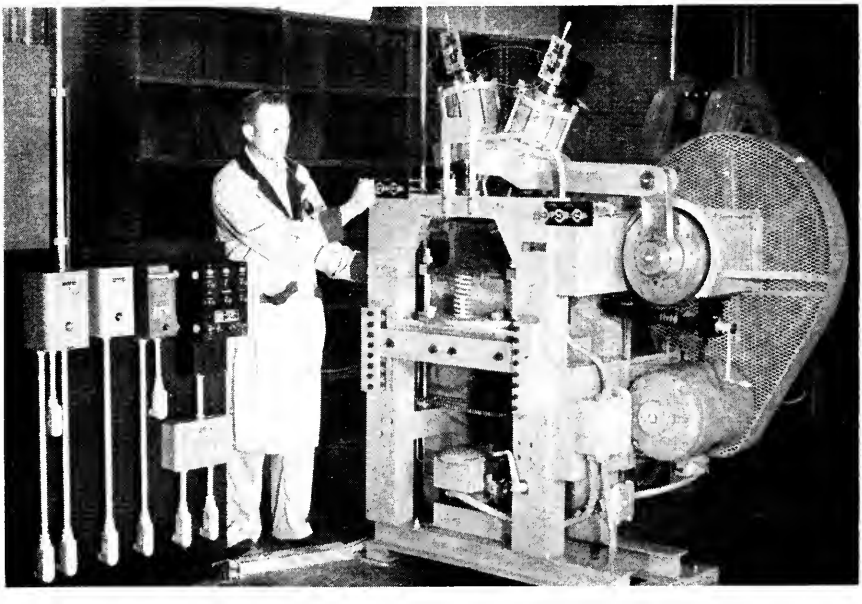


Fig. 28—Krouse tie wear testing machine.

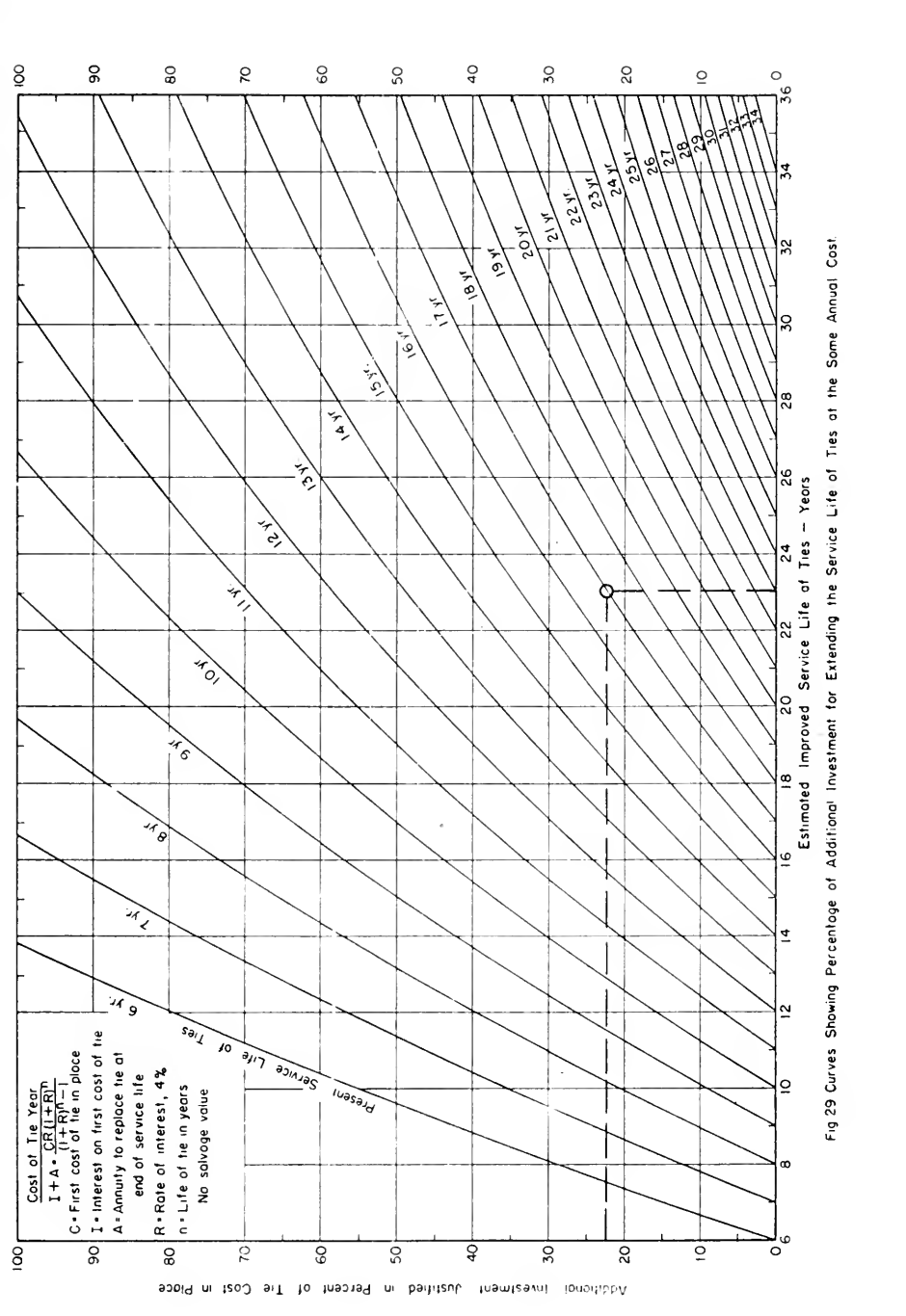


Fig 29 Curves Showing Percentage of Additional Investment for Extending the Service Life of Ties at the Same Annual Cost

Report on Assignment 7

Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings

R. G. Garland (chairman, subcommittee), John Ayer, Jr., E. G. Brisbin, J. T. Collinson, W. E. Cornell, W. E. Griffiths, G. W. Miller, L. A. Pelton, M. K. Ruppert, G. R. Sproles, R. E. Tew, Troy West, B. J. Worley.

This is the final report covering the eight-year service tests of the 1950 applications of metal preservatives in the joints of the northward main and of the five-year investigation of the spray method for preserving joints in both main tracks of the Illinois Central Railroad. This report is submitted as information which may be used at some later date as a basis of recommended practice in the protection of rail joints from corrosion and the prevention of frozen rail joints. This assignment will be continued, but with greater emphasis on reducing the corrosion of all other parts of the track structure.

This investigation is being made by the AAR research staff under the general direction of G. M. Magee, director of engineering research. H. E. Durham, research engineer track, is in direct charge of this assignment and is being assisted by other staff members.

Introduction

Originally the AAR–IC test installations included only the ten test sections (Nos. 1–10, incl.) made in the northward main in June 1950, as shown in Fig. 1, except for sections 3 and 10 which were changed to spray coat tests in July 1953, when that phase of the subject was initiated. It will be noted that the 1950 tests are located in two stretches of the northward main, south of Chebanse and Ashkum, Ill.

Because of the early failures of the brush coat applications of Dixon's 1924 Quick Drying Lubricant in section 3 and Farbertite in section 10, those sections were used to start the spray coat tests in 1953, as indicated in Fig. 1. In August 1955 the spray coat tests were started in the southward main between M.P. 74 and 76 where the 1944—131 RE rail had been laid with a brush coat of Texaco 45 on the 6-hole joints. No reapplication of a preservative was made inside the joints prior to the AAR tests. In the autumn of 1954 the joint bars in the 1944 rail were reversed, but no preservative was applied to the joints. Each spray coat test in the southward main includes the joints in one-half mile of rail. Extending south from M.P. 74 the four sections in the west rail are as follows: controls, Texaco 1965, Conoco 151 and No-Ox-Id 100, respectively numbered 11–W, 12–W, 13–W and 14–W. The east rail had only two sections south of the mile post: 11–E for controls and 12–E with No-Ox-Id 201. The control sections were used to compare the rail gaps with the lubricated sections.

This report includes the results of the inspection of the subcommittee, the performance of the test during the last service period of 12 months, ended August 1958, and a resumé of the more important developments. During the last test period the northward main carried 23 million gross tons, making a total of 243 million since the initial readings were taken in September 1950. The southward main carried 18 million gross tons in the last service period, making a total of 60 million since the tests were started in September 1955.

Maintenance of Way Report

During the last service period the IC reported that the track bolts in these tests had not been retightened out-of-face, and there were no stripped joints or broken

bolts, but some of the bolts had been replaced for other reasons. In sections 1–10, incl., of the northward main, one bolt was replaced in the north portion of section 1 and one bolt was found loose in section 8. In the southward main between M.P. 74 and 76, one bolt in section 12–E with No-Ox-Id 201 and six bolts in section 12–W with Texaco 1965 were replaced.

Inspection of Dismantled Joints

Eight committee members and guests were present at the inspection of 13 joints on April 21, 1958. The group included two representatives of two suppliers, four representatives of two railroads and two members of the AAR research staff. A light rain fell at the beginning of the inspection, and some of the photographs were taken while some areas of the joints were wet. Photographs of the joints are shown in Figs. 2 to 11, incl. The captions in the figures for the 1950 installations (Figs. 2 to 8, incl.) include comments on the conditions observed. As determined from previous inspections and this one, section 7 having the joints packed with Texaco 905 graphite grease and Plastic "H" end plugs has provided by far the best protection against corrosion of the 1950 installations. Section 8 with joints packed with Petrolatum (Dark) and Plastic H end plugs is ranked second. No hard rust slabs were found in the lower rail fillets of the joints packed with a preservative and end plugs. Some rust slabs covered by the end plugs in the joints without lubrication have been observed at previous inspections.

Figs. 7 to 11, incl., show the condition of the joints and spray compounds inspected, except the photographs of Joint No. 550 in section 12–E, SB main with 1944 rail, were missed. This one-half mile rail had the joints sprayed with No-Ox-Id 201, June 1956. The application was made with Dearborn Chemical Company equipment which had nozzles that would not pass by the bolts. This method is said to be used by railroads that protect the ends of the joints in the zones where the brine is blown in. All other sections since August 1955 were sprayed with a ⅛-in P 3504 flat jet nozzle and sufficient ⅛-in pipe to push the nozzle to the second bolt from the joint ends. This design of nozzle has a 3/64-in orifice and diverts the spray 40 deg upward and develops a horizontal spray angle from 20 deg at 15 psi pressure to 41 deg at 100 psi. This method provided complete coverage inside the joint. The Dearborn method did not fully cover the middle foot of the joint where the rail web failures generally occur.

A summary of the service performance of the spray compounds with respect to the capacity of each for controlling corrosion on the rail web in the joints is presented in Table 1. The performance factors of years of service per spray coat are given in the right column. Because the service conditions of the joints in the two main tracks were different, the factors are not suitable for precisely comparing the spray compounds in one track with the other one. The table will be helpful in determining the most economical spray compound to use for controlling corrosion of the rail web and unfreezing a sufficient number of joints to avoid broken bolts and stripped joints.

Summary and Conclusions

When the 132 RE rail was laid in the northward main in 1950, the rail was end hardened shortly after temporarily applying the joint bars. Approximately 10 to 20 min later the bars were removed and all of the metal preservatives were applied to the hot rail and bars, except that the end plugs were applied after completion of the relay work. The joints were pumped full of grease in sections 7 and 8 after the end plugs were applied. All of the brush coat applications on the hot rail and bars were seriously damaged in the middle foot of the 36-in headfree joint. This condition affected adversely the brush-coat application of Conoco Anti-Rust Compound, No-Ox-Id "A" Special,

(both petrolatum based) Stanolind Petrolatum (dark), Dixon's 1924 Quick Drying Lubricant and Farbertite. The last two compounds failed in two years and the sections were used for investigating the spray method of preserving and unfreezing joints.

Although the three petrolatum compounds were affected by the heat from the rail end hardening, each should be satisfactory as a brush coat on joints where the rail is end hardened in the mill. On the three compounds, petrolatum (dark) was inferior to the other two. Field end hardening of rail should be done before any rust preventive is applied to the joints.

There was some advantage to applying a brush coat to the rail ends and bars as opposed to treating the rail ends only. After four years of service, joints with the double application had better coverage on the rail and more preservative on the joint bars. Corrosive conditions in these tests were not severe, and only the rail ends needed a brush coat. Where brine drippings, sulfur droppings, brackish atmosphere, certain industrial contaminants or other corrosion accelerators exist, it seems justified to brush coat both the bars and rail ends.

From the condition observed in the joints having a brush coat of Conoco Anti-Rust Compound and both ends plugged, it was evident that the preservative was more effective and had a longer life than in joints without end plugs. Either with or without lubrication there were no adverse effects observed from plugging both ends of the joint bars. However, where no lubricant was used, a few rust slabs were found behind the end plugs in the lower rail fillets, which in later years could reduce the available take-up of the headfree bars.

In track with severe corrosion which causes the bolts to fail, the use of plastic H plugs in the receiving end of the joints, or in both ends if required, is a practical method of preserving the bolts. These tests have shown that square end plugs have better retention and require less material than the beveled ones.

The best joint preservation was obtained in section 7 where the joints were packed with Texaco 905 graphite grease and plastic H plugs. Section 8, where the joints were packed with petrolatum (dark) and plastic H plugs, provided the next best control of corrosion within the joints. After seven years of service, the plastic joint packing (formerly 1950 formula RMC packing) had become very dry and flaked out of one to three joint bar ends in most of the joints. A little oil was observed on the lower portion of the joint. The bolts were well preserved, but there was some corrosion on the rail web. Although the packing was packed at the ends of the bars to keep the ends closed, the material had become dry and was no longer serving as a good end plug. No fatigue cracks were found in the rail ends. The IC has reported no rail or joint bar failures in the 1950 installations.

The spray method was found to be an economical and effective operation for preserving and unfreezing joints. Table 1 gives a summary of the test. Two of the compounds, Texaco RCX–236 and No-Ox-Id 100, were difficult to heat sufficiently to get good atomization in warm weather with the Fairmont W 61, series B, oil sprayer.

The spray operation, as previously described, gave complete coverage in the joints and on the rail beyond the ends. With a better design of sprayer affording more latitude for heat and pressure, the same coverage should be obtained by pushing the nozzle just beyond the first bolt instead of the second.

The rail gaps measured in the test sections indicated that the gap uniformity was not significantly improved by the use of any preservative. There was a little improvement in one of the spray sections and in section 7 with Texaco 905 graphite grease.

In this test, as in the original test on the Burlington Railroad, the preservatives

used in the 1950 sections did not reduce joint wear as reflected by the joint-bar pull-in measurements. Section 7 was outstanding for a few years in having the most lubrication on the fishings. This section was in the upper range of pull-in values. The average pull-in values for sections with lubrication was slightly more than the average of the two sections (5 and 6) without lubrication. It, therefore, is obvious that when the joint slippage resistance becomes low because of good lubrication on the wearing surfaces, or from inadequate bolt tension, joints with low slippage resistance have more daily slippage movement due to the change in rail temperature. This excess wear apparently in some instances offsets the effect of lubrication. It is concluded that the chief benefits derived from the metal preservatives were reducing corrosion, preventing hard rust slabs, possibly avoiding corrosion fatigue failures in the rail and keeping a sufficient number of joints unfrozen to eliminate bolt breakage.

The bolts in all test sections were retightened on an annual basis except during the last service period. Very few of the bolts required replacement or became loose during a service period. There were no stripped joints. Because of this good performance, it is believed that the 10–4 rail anchorage arrangement per 39-ft length was adequate. A grease-type rust preventive that has good weather resisting properties should be applied to all track bolts when assembling joints.

In the test on the Burlington Railroad between Leland and Earlville, Ill. (Vol. 52, page 575), the rail ends were not hardened in the field and there was no damage to the brush coat applications. Furthermore, the test was not in the track subjected to brine drip, except a small amount blown by the wind from the adjoining main track. Of the brush-coat applications No-Ox-Id "A" Special and Petrolatum (Dark) were superior as to weather resisting properties in the five-year test. Leadolene No. 385 was classed as second best as to resisting the elements and controlling corrosion on the rail. In general, the petrolatum-based products have given good protection for about five years, except when damaged by the heat from end hardening rail.

Acknowledgement

The Association gratefully acknowledges the cooperation and assistance rendered by the IC and extends its appreciation to the suppliers for their assistance in conducting these tests.

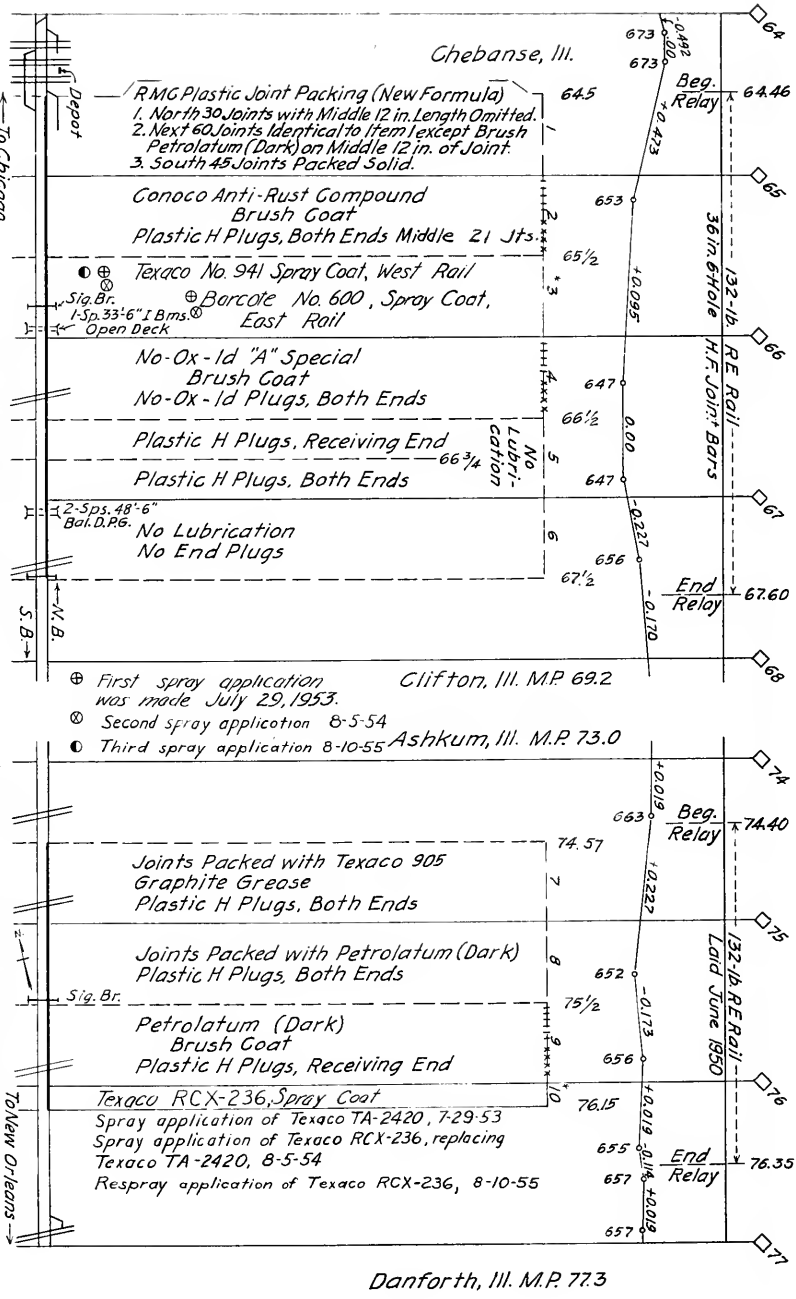


Fig. 1. – Rail Joint Lubrication Service Test in I. C. R. R. Northward Main Track Between Chebanse and Danforth, Ill.

* Sec. 3, Brush Coat, Dixon's Lubricant to 7-29-53
Sec. 10, Brush Coat, Furberlite to 7-29-53

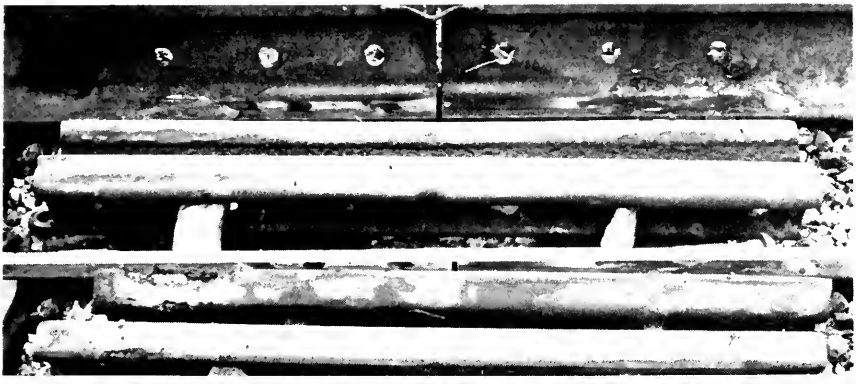


Fig. 2—North portion Section 4. Brush coat of No-Ox-Id "A" Special on rail and joint bars with No-Ox-Id end plugs. All end plugs were missing except a part of one. Joint was wet from rainfall and fairly free of debris. Extent of corrosion was moderate and no hard rust slabs were found in the lower rail fillets.

Fig. 3—South portion Section 5. Texaco plastic H plugs in both ends, no lubrication. All plugs were in place, but receiving end plugs were loose. Top view indicates rail gap had opened sufficiently to push the plugs from the bar ends. This joint was wet from rain. There were no slabs in lower rail fillets to reduce joint bar take up. The end plugs in this section had hardened from oxidation, but about 50 percent were intact.

Fig. 4—Section 6. No lubrication or end plugs. There was a little damaging corrosion in this joint. The hard rust slab at the receiving end of the field bar would prevent full take up of the headfree bars.

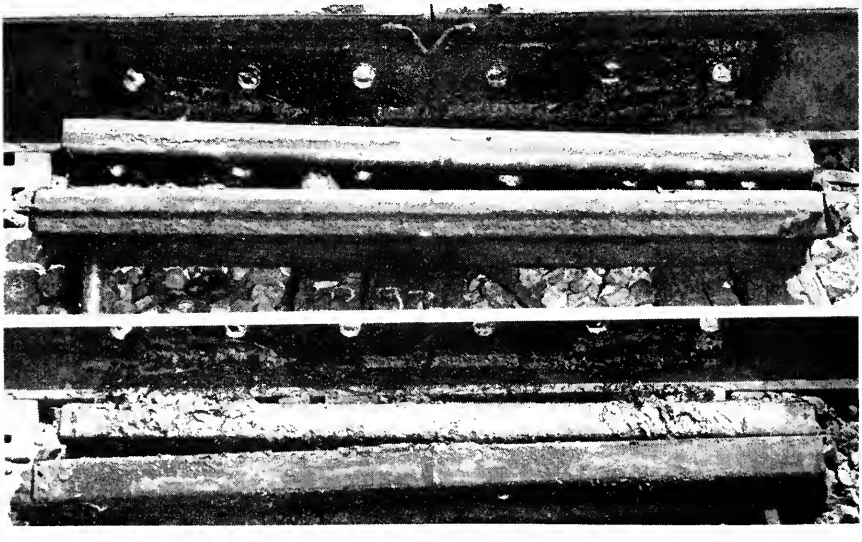


Fig. 5—Section 7. Packed with Texaco 905 graphite grease and plastic H end plugs. Although approximately 75 percent of the grease had whipped out, this joint was the best preserved one of the 1950 installations inspected. The bolts had a good coating of grease. The square end plugs used in Sections 7 and 8 have better retention than the beveled one.

Fig. 6—Section 8. Packed with Stanolind Petrolatum (Dark) and plastic H end plugs. Most of the grease had run out of the joint in hot weather, but there was a protective film left on rail web. The joints and bolts have had good protection but was somewhat inferior to that provided in Section 7 (Fig. 5).

Fig. 7—West rail section 3. Three years of service after three annual spray coats of Texaco 941.

Fig. 8—Section 10. Three years of service after one spray coat of Texaco TA–2420 and two annual coats of Texaco RCX–236.

Fig. 9—Section 12–W. Two years of service after two annual spray coats of Texaco 1965 on 1944 rail, SB main.

Fig. 10—Section 13-W. Two years of service after two annual spray coats of Conoco 151 on 1944 rail, SB main.

Fig. 11—Section 14-W. Three years of service after the first spray coat of No-Ox-Id 100 on 1944 rail, SB main.

TABLE 1. SUMMARY OF THE SERVICE PERFORMANCE OF SEVEN SPRAY COMPOUNDS

Name of Spray Compound	No. of Annual Spray Coats	Years of Effective Service			Years per Spray Coat
		Prior to Aug. 1958	Estimated Additional Life	Total	
NB Main 6-hole 132 HF Joint Bars in 1950 Rail					
Texaco 941	3	5	1	6	2.0
(1) Texaco RCX-236	3	5	1	6	2.0
Leadolene Barcote 600	2	3	0	3	1.5
SB Main 6-hole 131 HF Joint Bars in 1944 Rail					
Texaco 1965	2	3	1	4	2.0
Conoco 151	2	3	0	3	1.5
No-Ox-Id 100	1	3	1	4	4.0
No-Ox-Id 201	1	2	1	3	3.0

Notes: The spray tests were started when the 1950 rail was three years old and when the 1944 rail was 11 years old. Effective service is based on controlling rail web corrosion in the joints.

(1) One coat of Texaco TA-2420 was followed by two coats of RCX-236. Because the W 61 Fairmont oil sprayer failed to furnish adequate heat and pressure for this heavy material, only the third coat had proper atomization. Two coats for the service life shown would have been sufficient if good atomization could have been obtained for each application.

During the service tests, a little brine corrosion was observed in the southward main, but there was none in the northward main.

Report on Assignment 8

Laying Rail Tight with Frozen Joints

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This is a progress report on the service tests of tight rail as compared to rail laid with normal bolt tension and expansion on the Louisville & Nashville Railroad, the Erie Railroad, and the Bessemer & Lake Erie Railroad. The tight rail on the L&N is not end hardened, while the Erie and B&LE have end hardened and beveled rails. Bolt tension varies from 35,000 lb on the 1-in bolts of the Erie to 45,000 lb on the 1⅛-in bolts of the L&N and B&LE.

The investigation is under the supervision of G. M. Magee, director of engineering research, and H. E. Durham, who has charge of the assignment.

TEST ON LOUISVILLE & NASHVILLE RAILROAD

Introduction

The Louisville & Nashville Railroad laid a tangent section of tight rail near Chapel Hill, Tenn. in November 1953, with 132 RE section rail, 6-hole headfree joint bars, 1⅛-in track bolts, and 45,000 lb average tension on the bolts. The anchorage of this rail is described in Fig. 1.

Since October 1955, the AAR staff has obtained three periodic sets of data on the tight and normal rail, the last cycle extending from August 22, 1957, to August 7, 1958, ending a 0.94-year service period. The traffic carried by the test sections amounted to 10 and 39 million gross tons for the last service period and the total test period, respectively. Northward traffic was slightly heavier.

A complete description of the test is reported in the Proceedings, Vol. 57, 1956, pages 760–764.

Bolt Tension Measurements

The bolt tension measurements on 10 joints in the tight-rail installation were taken on August 7, 1958, ending a 2-year service period in 5 joints in the east rail and a 0.94 year service period on the 5 joints in the west rail. The 1-year cycle of applied 45,000 lb initial tension on the 1⅛-in bolts was prolonged on the joints in the east rail to study the effect of a probable longer maintenance cycle of tightening.

The bolt-tension-loss table presented below shows that the middle bolts of the joints in the west rail had lost 40 percent of the applied tension in 0.94 year. Intermediate and end bolt losses were 21 and 19 percent, respectively. This compares with 40, 24 and 31 percent losses on the middle, intermediate and end bolts in 1957.

On the bolts in the east rail joints for a 2-year span, the losses had increased to 60 percent on the middle bolts and 41 percent on the remaining bolts. Average loss for the joints was 47 percent or 23,500 lb remaining tension after 2 years. One-year loss averaged 27 percent for the joints or 32,600 lb remaining tension. From an analysis of the joint gap pattern occurring during the prolonged period of bolt maintenance, it appears that the 2-year span had no adverse effect on the general maintenance of the installation.

Bolt Tension Test in Tight Rail on Louisville & Nashville Railroad Near Chapel Hill, Tenn.

(Six-Hole 132-lb Headfree Joint Bars, 1⅛ in Bolts, Single Coil Spring Washers)

Bolt Position	*Average Bolt Tension in 1000 Lb* Initial	Final	Loss	Percent Loss
East Rail	*8–8–56 to 8–7–58*		*Two Year Loss*	
Middle Bolts	44.4	17.6	26.8	60
Intermediate Bolts	45.3	26.9	18.4	41
End Bolts	44.3	26.0	18.3	41
Avg. All Bolts	44.7	23.5	21.2	47
West Rail	*8–22–57 to 8–7–58*		*One Year Loss*	
Middle Bolts	44.2	26.5	17.7	40
Intermediate Bolts	45.7	36.2	9.5	21
End Bolts	43.7	35.3	8.4	19
Avg. All Bolts	44.5	32.6	11.9	27

Rail Joint Gaps and Cumulative Rail Creepage

Creepage of the rails and winter rail gaps for the tight and normal rails were recorded by the L&N staff on January 8, 1958, with a rail temperature of 12 deg (Figs. 1 and 2). Patterns of the summer rail movement and gaps of both installations, taken by the AAR on August 6, 1958, at an average rail temperature of 126 deg, are shown in Figs. 3 and 4.

The tight rail gaps, as shown in the lower left portion of Fig. 2, indicate 16 open joints in the east rail with an average gap of 0.014 in at 12 deg. This compares with 14 open joints averaging 0.13 in at 22 deg in December 1956. The average gap for the 211 joints decreased from 0.009 in. in December 1956 to 0.001 in. in January 1958. The normal rail gaps dropped from an average of 0.21 in to 0.17 in during the same period, indicating an increase in the joint slippage resistance. Only one of the tight rail joints has repeatedly been open during the last three winters.

Fig. 4 represents the rail gap pattern for the tight and normal rail taken at 125 deg and 128 deg, respectively. The average gap in the tight rail for 5 open joints was 0.055 in as compared with 6 joints open at 0.015 in at 111 deg last year. The average gap for all the joints was 0.001 in as compared to 0.0004 in last summer. During the same period, the average rail gap in the normal rail increased from 0.06 in to 0.084 in.

The pattern of rail movement as indicated for the tight and normal rail in Figs. 1 and 3 shows little change from the previous cycle of measurements. Normal rail creepage during a year is moderately greater than the tight-rail movement. The anchorage on the normal rail consists of 8–8 drive-on anchors boxed per rail; whereas, the tight rail has compression clips for anchors and is confined at each end with eight panels of drive-on anchors, which are boxed on all ties except at the joints.

The bolts in the normal rail joints were retightened in October 1957 with a tension ranging from 15,000 lb to 25,000 lb. A tension of 45,000 lb was applied in August 1958 to the tight rail joints.

From a study of the joint gaps taken during the last cycle, it appears that the deferred tightening of the tight rail for a two-year duration had no adverse effect on the number or size of the gaps.

Rail Surface Profiles

Fig. 5 of this report indicates the difference in the profiles of 20 joints in each of the tight and normal rail installations between October 1955 and August 1958. Most of

the tight-rail profile has dropped below the original profile this year which represents a substantial change from the last cycle when the profile from the 2-in point outward had bowed up above the original. The average rail-end batter on the non-hardened tight rail at the ¼-in points has increased to approximately 0.02 in.

The normal rail has continued to show some progressive wear. However, the end-hardening of the rail in this installation has apparently retarded the batter at the ¼-in points which remained at 0.005 in, the same as last year.

Rail End Chipping

Because of the break-out or chipping of the metal in the rail ends of the tight joints, it was necessary to gas weld 65 of the 211 joints during the previous service cycle. Inspection of these welds this year revealed that the majority were performing well. Among the joints which had not been welded were some which continued to show additional chipping of the rail ends. In some of these cases, the rail steel had flowed and partially filled the chipped-out portion of the rail end.

The normal rail ends have little batter and will not require repair by welding for several years.

Maintenance of Way Report

Maintenance costs on the tight and normal rail, as reported by the L&N, was $11.51, for tamping a low joint in the tight rail. The bolts in both test sections were retightened during the last service period, but no work was performed on the tight rail compression clips.

TIGHT RAIL TEST ON THE ERIE RAILROAD

Introduction

In July 1957 the Erie Railroad installed 1.74 miles of tight rail in the eastward main track near Crown Point, Ind., using 115 RE rail, 6-hole long-toe bars, 13-in tie plates, 1-in track bolts with spring washers, and an average bolt tension of 40,000 lb. Subsequent retightening of the bolts was for 35,000 lb tension. All the rail ends were hardened, beveled, and end milled with slight undercut. An additional amount of 675 cu yd per track mile of crushed rock ballast was provided to increase the shoulder width, and each rail was anchored with compression clips on all ties, except both ends of the joint ties, averaging 19 clips per rail. End zone anchorage consisted of 15 rails with clips (see Vol. 59, page 1074).

West of the tight-rail section, a track mile of normal rail, laid previously in April 1957, similar to the tight-rail construction except for eight forward and two back-up grip-type anchors, was included in the test as a basis of comparison. The normal rail ends were not end milled. The normal rail was laid with the temperature ranging from 60 to 80 deg (average 70 deg) while the tight rail ranged from 66 to 90 deg (average 80 deg) on the south rail, and 70 to 111 deg (average 97 deg) on the north rail.

On the afternoon of May 14, 1958, 20 members and guests of the Track committee made an inspection of the Erie tests. The Erie furnished bus transportation from Hammond, Ind. and members of its staff and the AAR escorted the group over the test track.

Traffic over the test track during the service period covered by this report was 7.7 million gross tons, including all freight and passenger cars and locomotives.

Rail Joint Gaps and Cumulative Rail Creepage

Initial measurements of the tight rail gaps were recorded on September 17, 1957, at a rail temperature of 104 deg. Of a total 266 joints, there were 34 open joints in the

north rail with an average gap of 0.10 in and 26 open joints in the south rail with an average gap of 0.05 in, as shown in the upper half of Fig. 6. The over-all average gap for the north and south rails was 0.02 in and 0.01 in, respectively. Normal rail gaps taken at 100 deg rail temperature averaged 0.04 in on the north rail and 0.06 in on the south rail with 135 joints in each rail, as shown in the lower half of Fig. 6.

Fig. 7 depicts the creepage of each rail throughout the normal and tight rail tests as measured at the end points, ¼ points, and centers of the test miles on December 11, 1957. Both of the sections show moderate amount of movements measuring as much as ½ in during the winter. The north rail moves with the traffic, but the south rail for the most part moves west or against traffic.

The first winter gap readings are categorized in Fig. 8. At 4 deg rail temperature, 167 out of 266 joints were open, and 99 or 37 percent were closed completely. The average gap was 0.16 in for the open joints and 0.10 in for the whole section. In comparison, the normal test at 15 deg rail temperature averaged 0.21 in gap for 270 joints.

For a closer analysis of the first winter gap readings, Fig. 9 is presented to show the pattern by separate rails. The diagram indicates that there are seven fewer open joints in the south rail than in the north rail of the tight rail section. This, therefore, causes a higher percentage of closed joints to occur in the south rail where the rail was laid at 80 deg as compared to 97 deg for the north rail. The normal north rail lacks uniformity in gaps; whereas, the normal south rail, as shown in the lower right corner of Fig. 9, indicates better uniformity. Both rails were laid at 70 deg initially.

Figs. 10, 11 and 12 repeat the same type of measurements as previously mentioned, as recorded on September 22, 1958, at 114 deg and 111 deg on the tight and normal rail, respectively. The bolts were retightened in the tight rail to 35,000 lb tension on August 22, 1958, at which time the bolts were released to close the open joints and then retightened. There was only one joint that would not close. It will be noted in Fig. 10 that during the higher temperatures, the creepage was eastward with the traffic for both rails. The number of open joints during the summer had reduced to 63 (Fig. 12); 37 with an average gap of 0.08 in. in the north rail, and 26 in the south rail with an average gap of 0.06 in. Again, the large number of tight joints occurred in the south rail because of the lower rail-laying temperature.

The summer normal rail gap readings, also taken at 111 deg, as shown in the lower half of Fig. 12, indicate more closed joints in the north rail having an average joint gap of 0.02 in. Average joint gap for the south rail was 0.05 in. The bolts in the normal rail were retightened to about 20,000 lb September 4, 1958.

Rail Surface Profiles

In the tight rail, the profile of the rail surface, as shown in Fig. 13, shows no increase in batter from the original profile but indicates a general decrease in the height of the rail surface over the joint. The normal rail indicates no increase in batter and shows a relatively slight decrease in rail height. This increase in joint droop in the tight rail may have been influenced by the high bolt tension used. Both of the normal and tight-rail sections have long-toe headfree joint bars. There was no significant difference in the rail end batter of the two test sections.

Maintenance of Way Report

The Erie retightened, raised and lined the joints in both tight and normal rail sections during the last service period at a labor cost of $619 for the tight rail and $679 for the normal rail. The expense for raising and lining should not recur frequently. There was no expense maintaining the anchors or respacing ties. There were no loose, broken or missing bolts.

TEST ON BESSEMER & LAKE ERIE RAILROAD

Introduction

The tight rail service test installation on the B&LE near Grove City, Pa., was laid in October 1957 (See Vol. 59, page 1075). The rail is 140 RE with 140 AREA 6-hole head-contact joints, bolt hole spacing 7–6–5½–6–7 in, 1⅛-in bolts and plain 11/64-in carburized washers. Typical joints are shown in Figs. 14 and 15 and described in Fig. 17.

Following a meeting in Pittsburgh on the morning of April 16, 1958, 26 committee members and guests journeyed to Grove City for inspection of the tight rail test during the afternoon.

The initial test measurements of top of rail profile, joint gap, out-to-out of joint bars, bolt tension and rail creepage were obtained by the AAR research staff on November 20 and 21, 1957. The B&LE took winter readings of joint gap and rail creepage on February 10, 1958, and a complete set of measurements were again made by the AAR on August 11 and 12, 1958. The traffic for the first service period beginning November 20, 1957, was approximately 6.8 million gross tons, of which about 60 percent was southbound made up chiefly of loaded ore cars of 90-ton capacity. Because of the limited steel mill operations during 1958, the tonnage has been considerably less than normal.

Bolt Tension Measurements

As in the L&N test and as stated in the previous report, 45,000 lb tension was determined as a practical maximum for 1⅛-in bolts. The power wrench was set accordingly during laying of the rail and for subsequent tightening about one month after laying in 1957 and during early summer 1958.

On November 20, 1957, six joints were set up to determine loss of bolt tension and these were checked on August 11, 1958. The results obtained were as follows:

Average Bolt Tension in 1000 Lb

	November 20, 1957, to August 11, 1958			*Percent*
Bolt Position	*Initial*	*Final*	*Loss*	*Loss*
Middle Bolts	44.9	25.7	19.2	43
Intermediate Bolts	45.6	32.5	13.1	29
End Bolts	44.5	29.9	14.6	33
Avg. All Bolts	45.0	29.4	15.6	35

It will be noted that the middle bolts lost 43 percent compared with 29 and 33 percent, respectively for the intermediate and end bolts during the first test period consisting of 0.72 year. At the time of laying, all bolts were dipped in Texaco 904 grease before application of the nuts for the purpose of obtaining the proper bolt tension with the minimum torque and to avoid damage to the threads.

Rail Joint Gaps and Creepage

Initial gap readings obtained on November 21, 1957, are shown in Fig. 16. At the time of laying, all rail ends were bumped tight, but loss of bolt tension in the first month after laying was sufficient to permit considerable opening of the joints with relatively low temperatures during the period. Steel bars were driven into the ballast at the ends and each ¼ mile to obtain cumulative rail creepage.

The winter gap readings, obtained on February 10, 1958, as shown in Figs. 18 and 19, show a pattern similar to the initial readings with an increase of 18 percent

in the number of open gaps in the end-hardened rail and 19 percent increase in the plain-end rail. The increase in average gap was 49 percent in the end-hardened rail and 33 percent in the plain-end rail. It would appear that the anchorage on the plain-end rail was somewhat more effective than that on the north ½ mile.

The rail creepage when the winter readings were taken (Fig. 17), indicated that the rail was pulling into the test mile at each end an average of 0.19 in on the north end and 0.15 in on the south end. The movement at the intermediate points was small.

Summer gap readings obtained on August 11, 1958, are shown in Figs. 21 and 22. The difference between winter and summer temperatures was 113 deg for the north one-half of the test and 110 deg for the south one-half. It will be observed that there was a decided change in gap pattern in both sections; 91 percent of the joints being closed in the plain-end rail and 77 percent closed in the end-hardened rail.

It is somewhat difficult to evaluate the summer gaps from the standpoint of slippage for the reason that the B&LE loosened the joint bars and permitted the rail to close the gaps during June 1958. Fourteen of the open joints in the end-hardened rail were found closed at the base, and four in the plain-end rail were similarly closed at the base although a slight gap existed at the head due to the end milling not being uniform.

Rail creepage on August 11, 1958, shown in Fig. 20, indicates movement out of the test mile at each end, an average of 0.19 in at the north end and 0.23 in at the south end. Relatively little movement occurred at the intermediate points.

Rail Surface Profiles and Joint Bar Pull-In

Fig. 23 shows the rail surface profiles measured in November 1957 and August 1958. This test mile has two short curves of 1½ deg and 1 deg on the end-hardened rail and plain-end rail, respectively. Profile readings were taken at 10 joints of each rail, both curve and tangent on end-hardened rail and plain-end rail. The traffic was approximately 1.5 million gross tons from the time of laying the rail until the profile readings were taken in November 1957. It will be observed that the plain-end rail had already acquired a small amount of end batter, which changed very little in the test period of 0.72 year although the profiles are a little lower. End batter on the end-hardened rail is slight, but the profiles have lowered about the same as in the plain end rail.

Maintenance

The only maintenance on the test mile since laying of the rail and final surfacing was retightening of the bolts in November 1957, just before setting up the test and releasing the bars to close the gaps, following by retightening on June 20, 1958, when all of the open joints were closed by first releasing the bolt tension.

GENERAL REMARKS

In the L&N tight-rail test the average loss in bolt tension was 47 percent for a two-year period. During the second winter of that period, only 16 open joints were reported when the rail temperature was 12 deg. These open joints had gaps of either 0.01 in or 0.02 in. Because of this good performance, the L&N has agreed to retighten the 1⅛-in bolts to 45,000 lb biennially.

After the L&N tight-rail test section was three years old and had carried about 40 million gross tons of traffic, it was necessary to build up by welding 65 of the 211 test joints. This work was caused by deep chipping. The rail ends had been end-milled

with too much undercut which concentrated the compressive thermal force in the upper portion of the rail head.

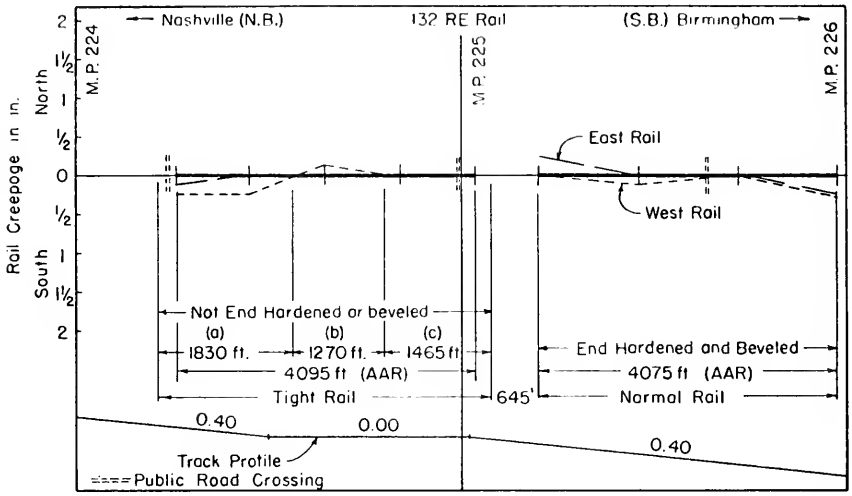
Members of the AAR research staff inspected five test locations of tight rail on the Chesapeake & Ohio Railway, three of which had carried 40 million gross tons prior to the observations made in May 1958. The three tests were laid with the rail ends milled but not hardened or beveled, the same as in the L&N tests. There was no chipping of the rail ends. This was attributed to having the rail ends prepared with good square cuts and minimum undercut for closing the rail gap at the running surface. From this observation, it is evident that to avoid chipping of the soft rail ends in rail laid tight with frozen joints, preparation of the rail ends must be done accurately.

In the three test locatons, only the tight-rail section on the Erie was laid at an unfavorable rail temperature for freezing the joints. The first summer temperature check of the rail gaps was made in September 1957 at an average rail temperature of 104 deg, and 23 percent of the 266 joints were open. On September 22, 1958, there were 24 percent open joints at a rail temperature of 114 deg. All of the tight-rail bolts had been retightened and all joints found open were closed, except one on August 22, 1958. The check of the gaps on December 11, 1957, at a rail temperature of 4 deg indicated 63 percent of the joints were open, with an average gap of 0.16 in. If in the coming winter there is no significant increase in the number of frozen joints, consideration should be given to driving up the rail tight at a mean rail temperature of 55 or 60 deg.

The AAR staff suggested the use of head-contact bars in the B&LE tight rail test because these joints build up a slippage resistance greater than the headfree type. This should accelerate the "freezing" of the joints. Because high bolt tension with coil-spring washers is damaging to the nuts, and to the bolts to a lesser extent, carburized plate washers as used with high-tensile bolts in structural steel were also suggested. In the first month of service and the next nine months, the loss in bolt tension is judged to be higher than in other tests. Additional information on the loss in bolt tension will be developed during the second year of service.

Acknowledgement

The AAR is grateful to the L&N, Erie and B&LE for their assistance and cooperation given in these tests.



Note: Rail laid tight is anchored with compression clips as follows: (a). Field end of all tie plates, except at the joints. (b). Field end of alternate tie plates. (c). Gage end of alternate tie plates. End zone anchorage consists of 8 track panels with all ties boxed, except at the joints. Normal rail is anchored with 8-8 grip type anchors boxed per rail.

Fig. 1. Rail Creepage, January 8, 1958, L & N RR, near Chapel Hill, Tenn.

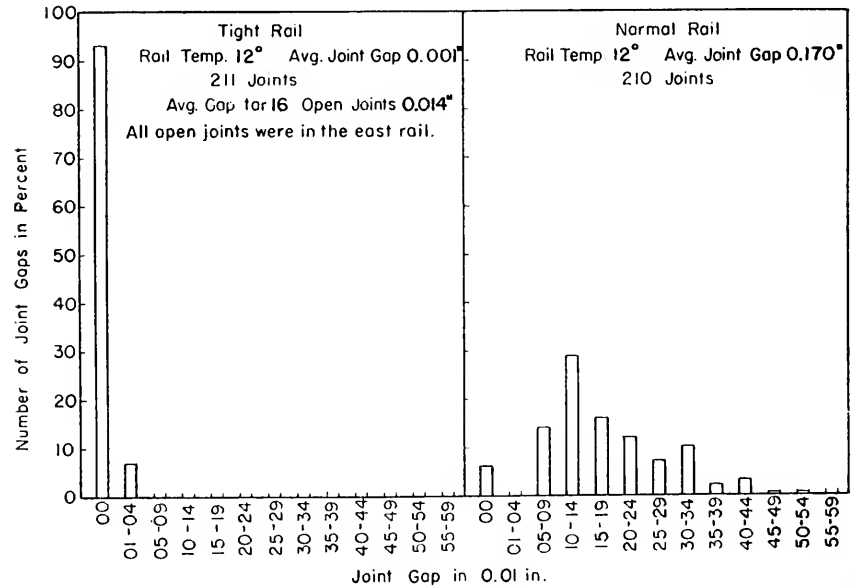
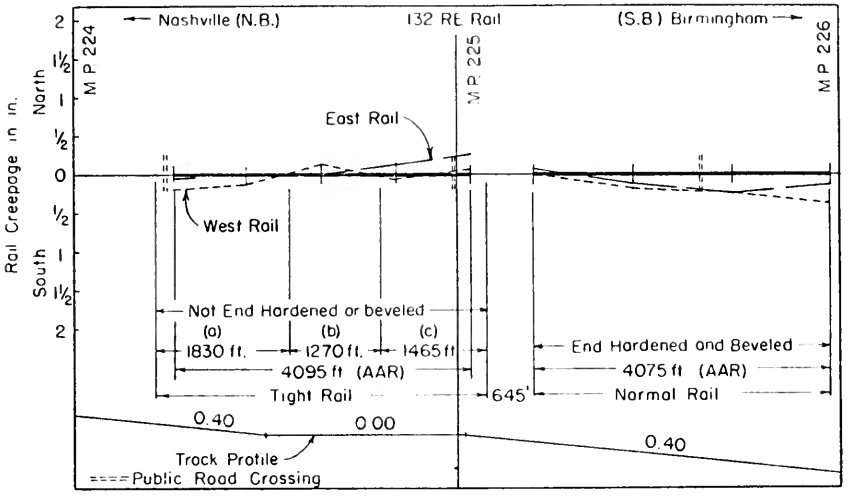


Fig. 2. Joint Gap Measurements for Tight and Normal Rail, January 8, 1958, L&N RR, near Chapel Hill, Tenn.



Note: Rail laid tight is anchored with compression clips as follows: (a). Field end of all tie plates, except at the joints. (b). Field end of alternate tie plates. (c). Gage end of alternate tie plates. End zone anchorage consists of 8 track panels with all ties boxed, except at the joints. Normal rail is anchored with 8-8 grip type anchors boxed per rail.

Fig. 3. Rail Creepage, August 6, 1958, L & N RR, near Chapel Hill, Tenn.

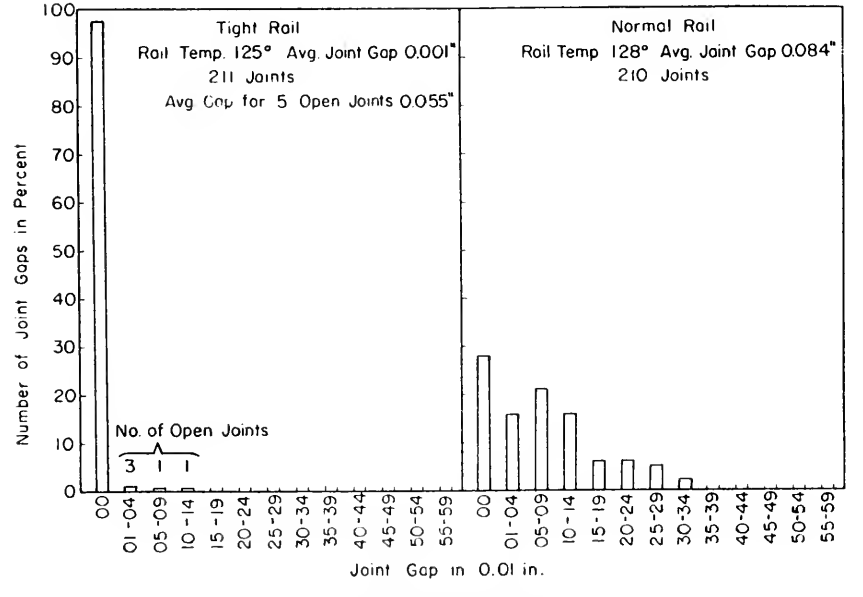
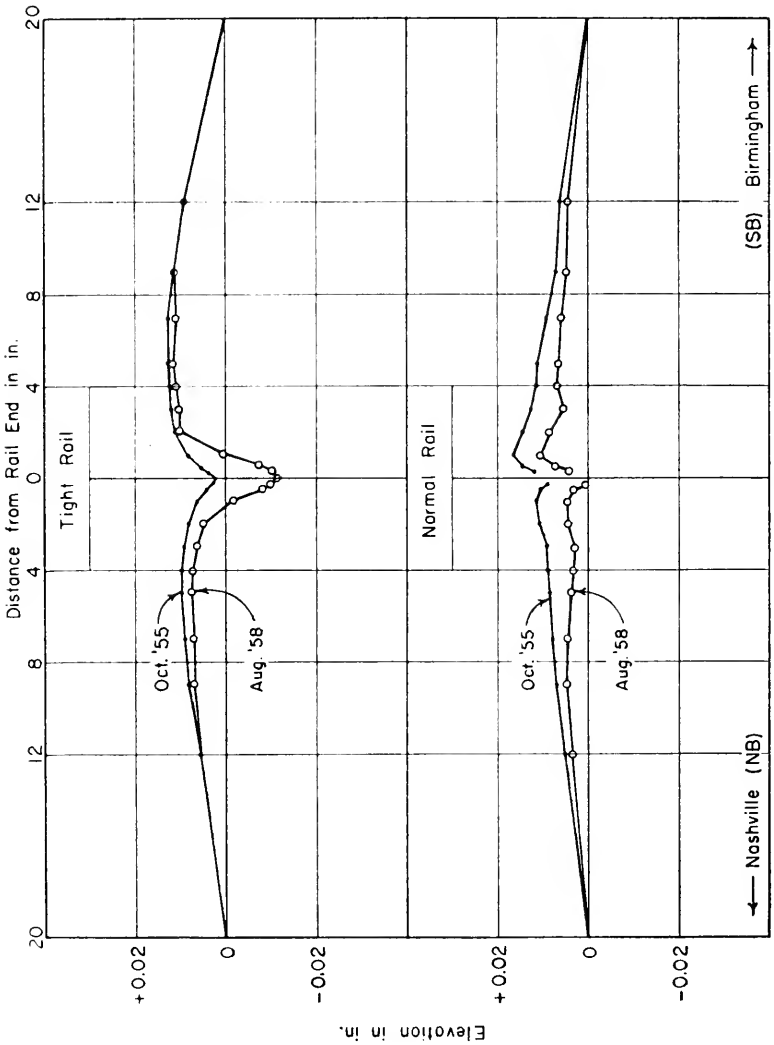


Fig. 4. Joint Gap Measurements for Tight and Normal Rail, August 6, 1958, L&N RR, near Chapel Hill, Tenn.



Note: Profile elevations are the average of 20 joints, 10 in each rail.

Fig. 5. Rail Surface Profiles, L&N RR, near Chapel Hill, Tenn.

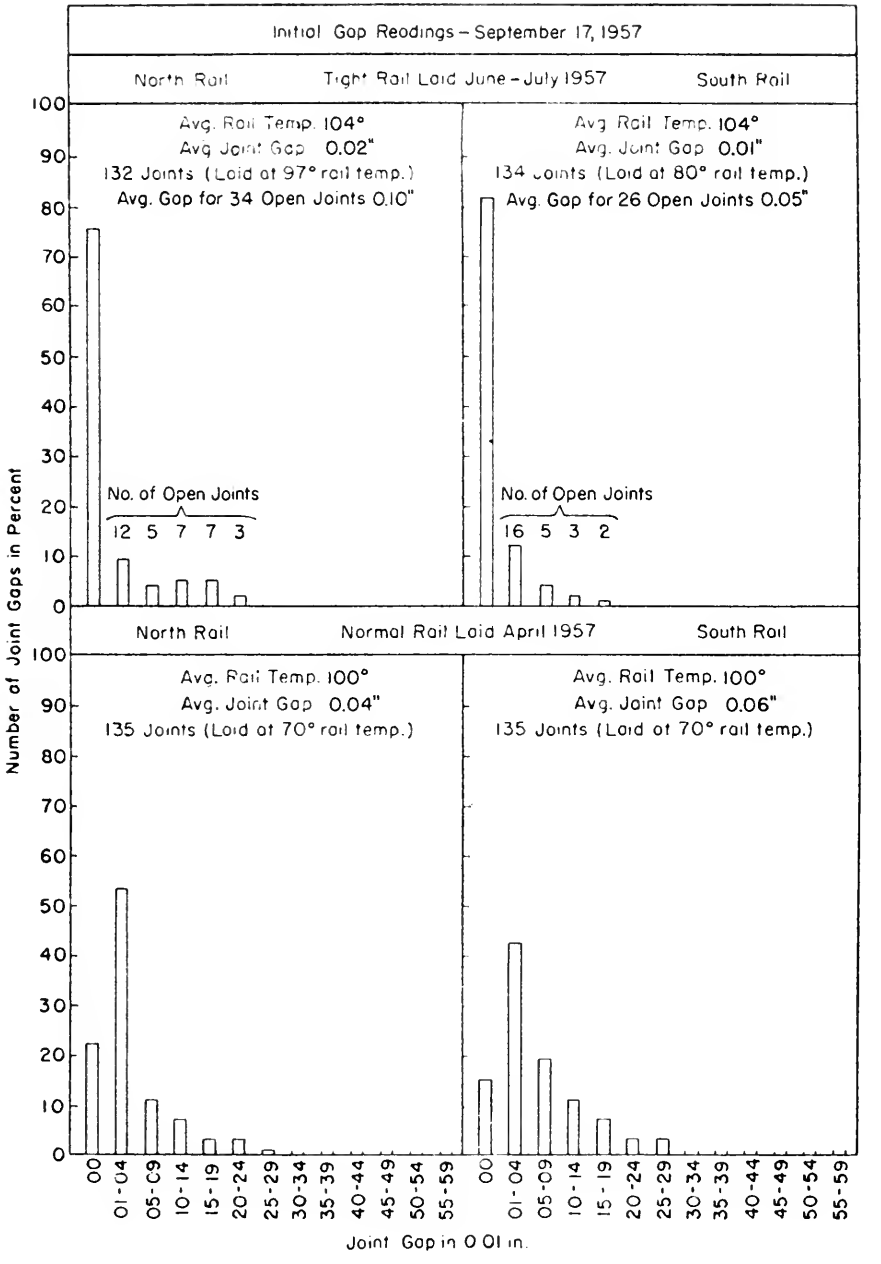
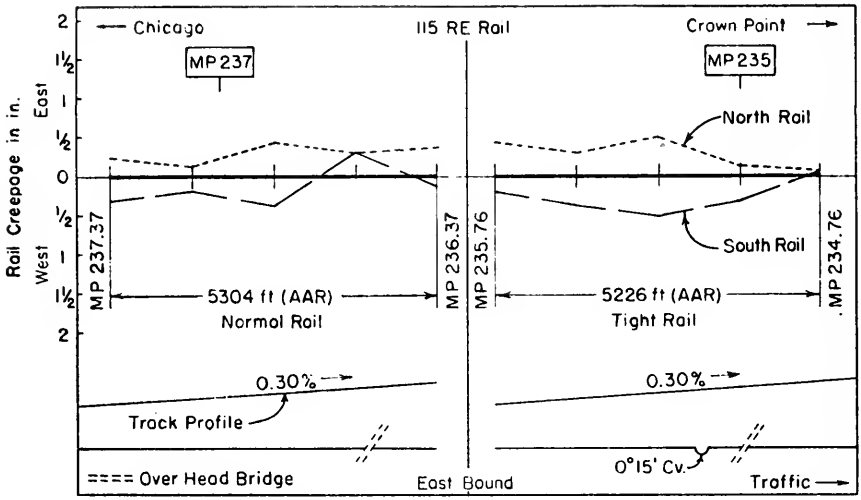


Fig. 6. Joint Gap Measurements in Tight and Normal Rail, Erie RR, near Crown Point, Ind.



Note: Rail laid tight is anchored with 19 compression clips per rail. Normal rail is anchored with 8-2 grip type anchors per rail. All rail is end hardened and beveled.

Fig. 7. Rail Creepage, December 11, 1957, Erie RR, near Crown Point, Ind.

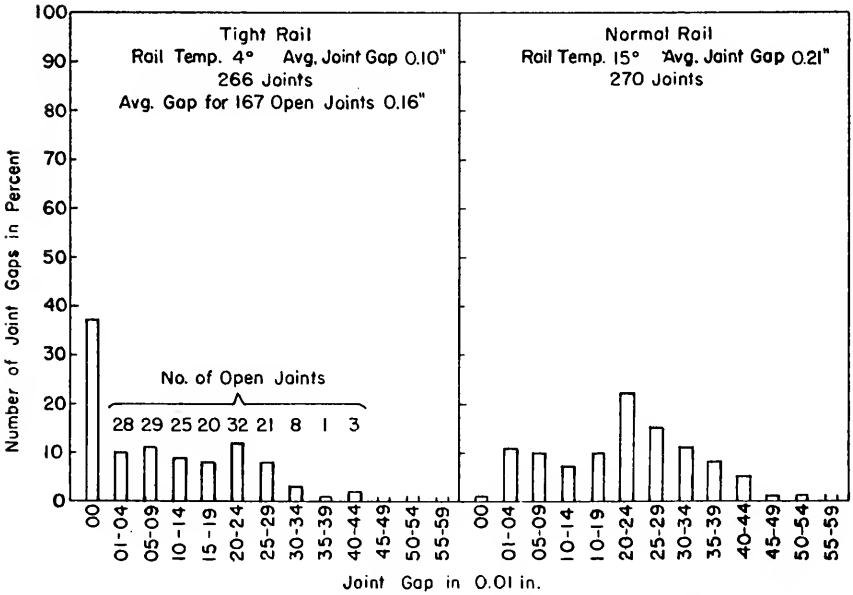


Fig. 8. Joint Gap Measurements for Tight and Normal Rail, December 11, 1957, Erie RR, near Crown Point, Ind.

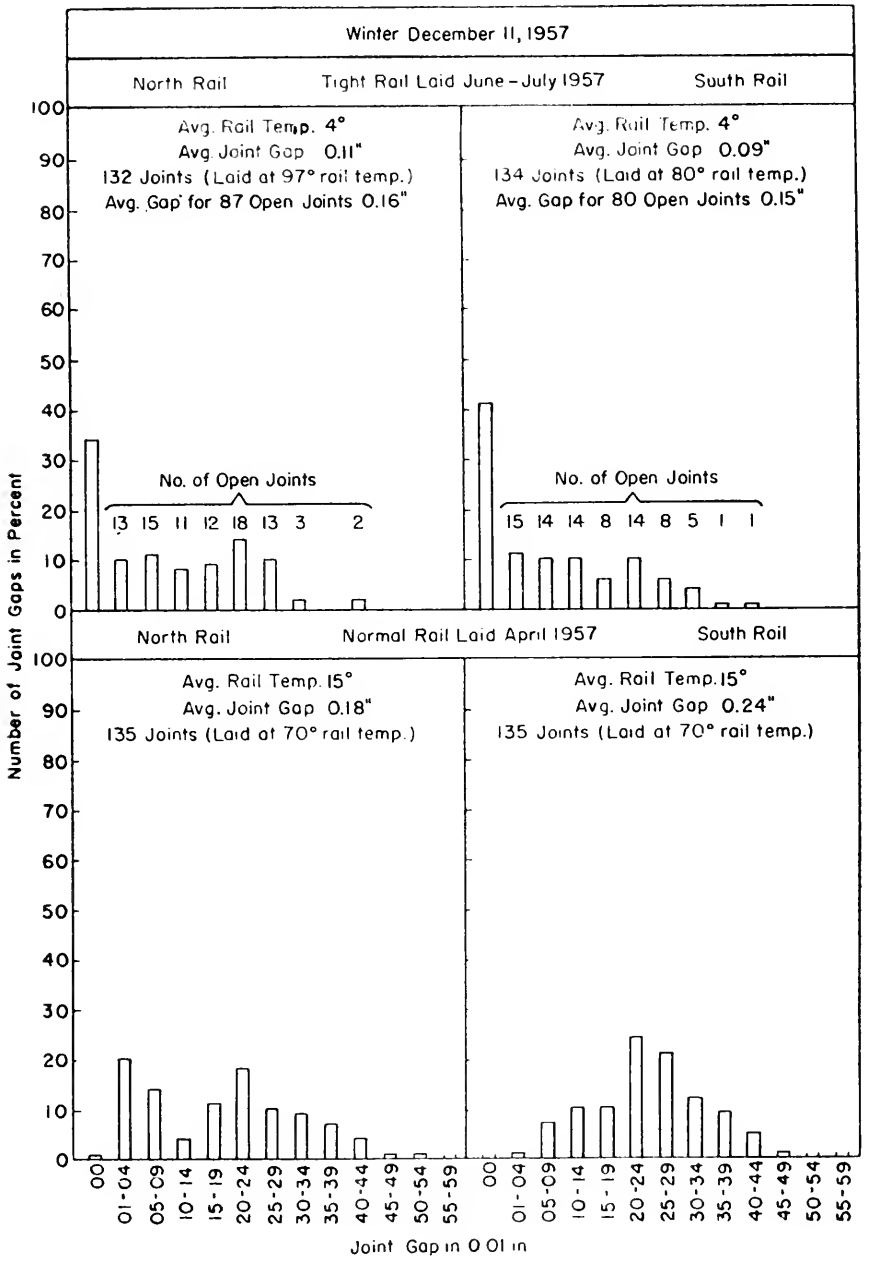
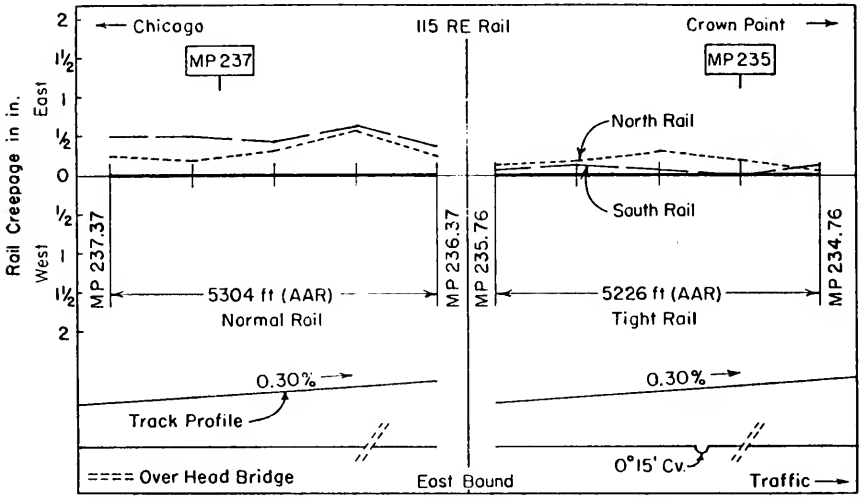


Fig. 9. Joint Gap Measurements in Tight and Normal Rail, Erie RR, near Crown Point, Ind.



Note: Rail laid tight is anchored with 19 compression clips per rail. Normal rail is anchored with 8-2 grip type anchors per rail. All rail is end hardened and beveled.

Fig. 10. Rail Creepage, September 22, 1958, Erie RR, near Crown Point, Ind.

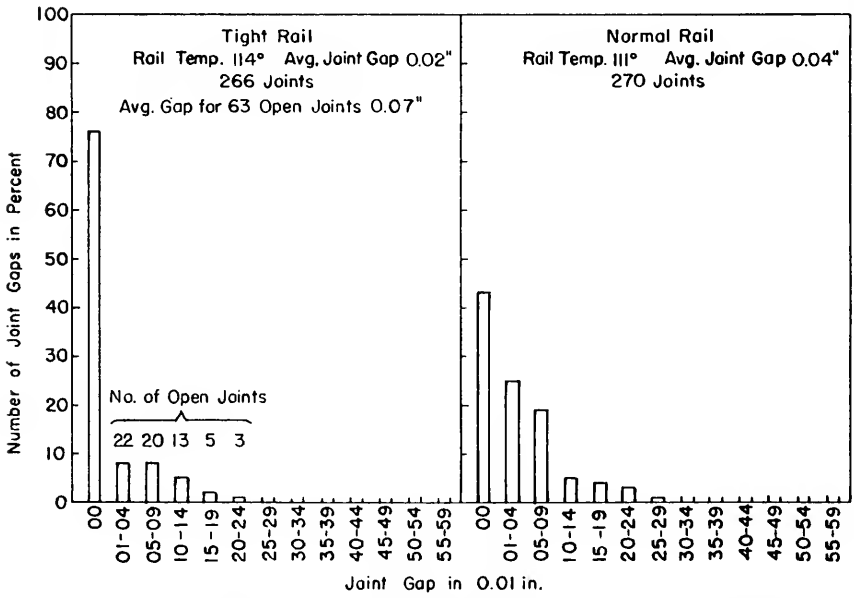


Fig. 11. Joint Gap Measurements for Tight and Normal Rail, September 22, 1958, Erie RR, near Crown Point, Ind.

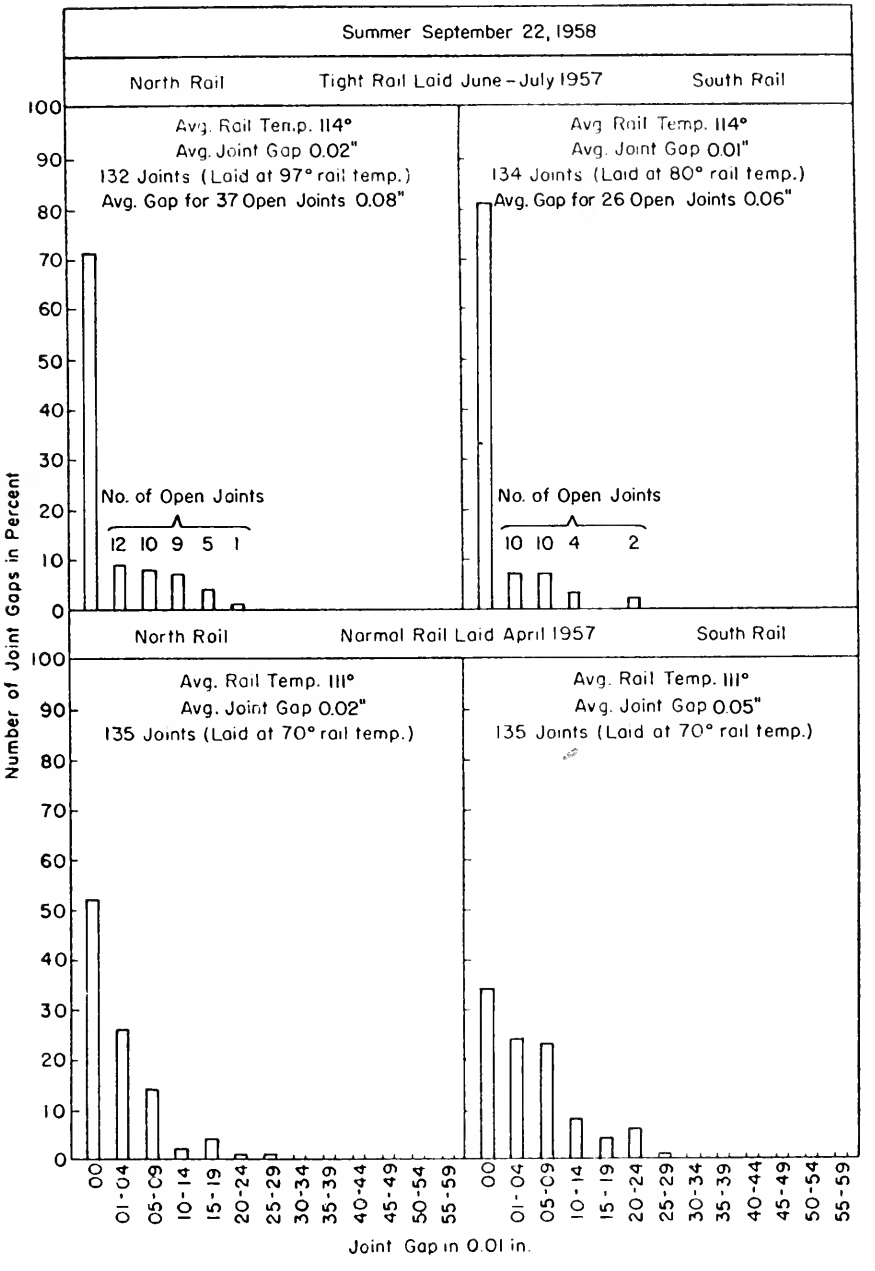
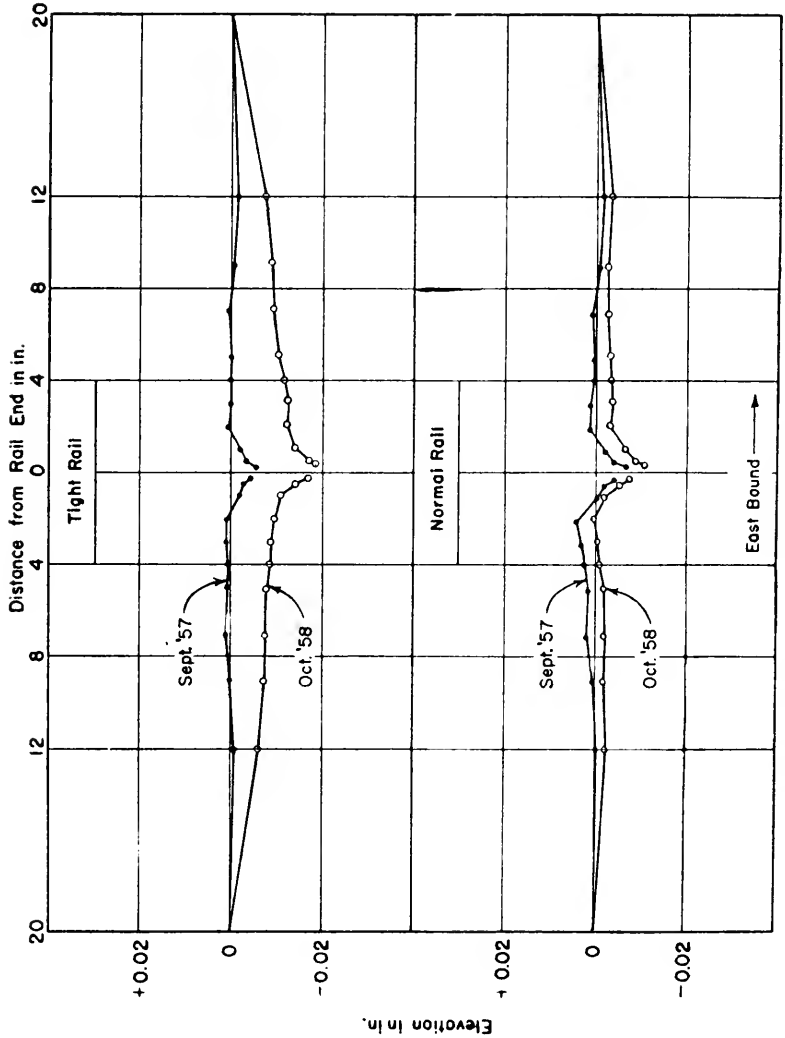


Fig. 12. Joint Gap Measurements in Tight and Normal Rail, Erie RR, near Crown Point, Ind.



Note: Profile elevations are the average of 20 joints, 10 in each rail.

Fig. 13. Rail Surface Profiles, Erie RR, near Crown Point, Ind.

Fig. 14—B&LE typical tight joint in north one-half mile. End-hardened beveled-end rail.

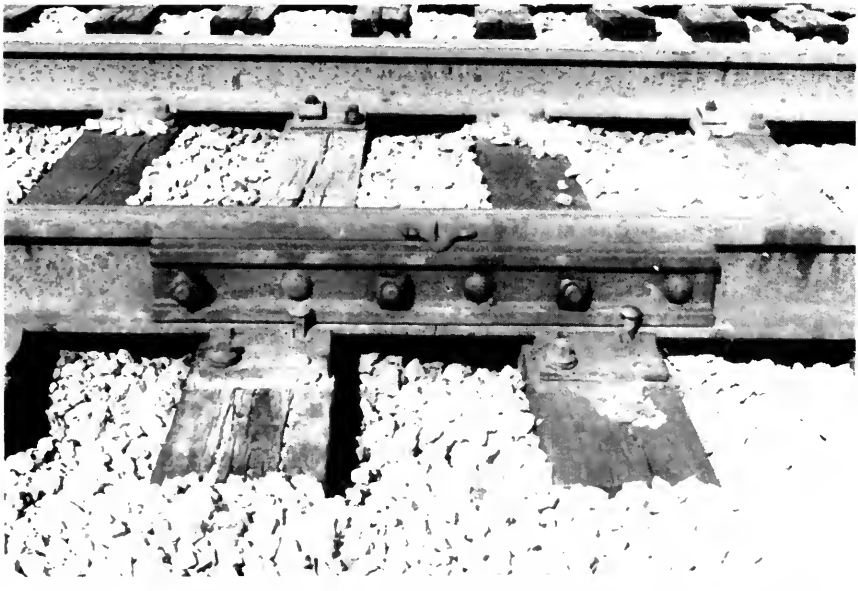


Fig. 15—B&LE typical tight joint in south one-half mile. Plain-end rail not hardened or beveled.

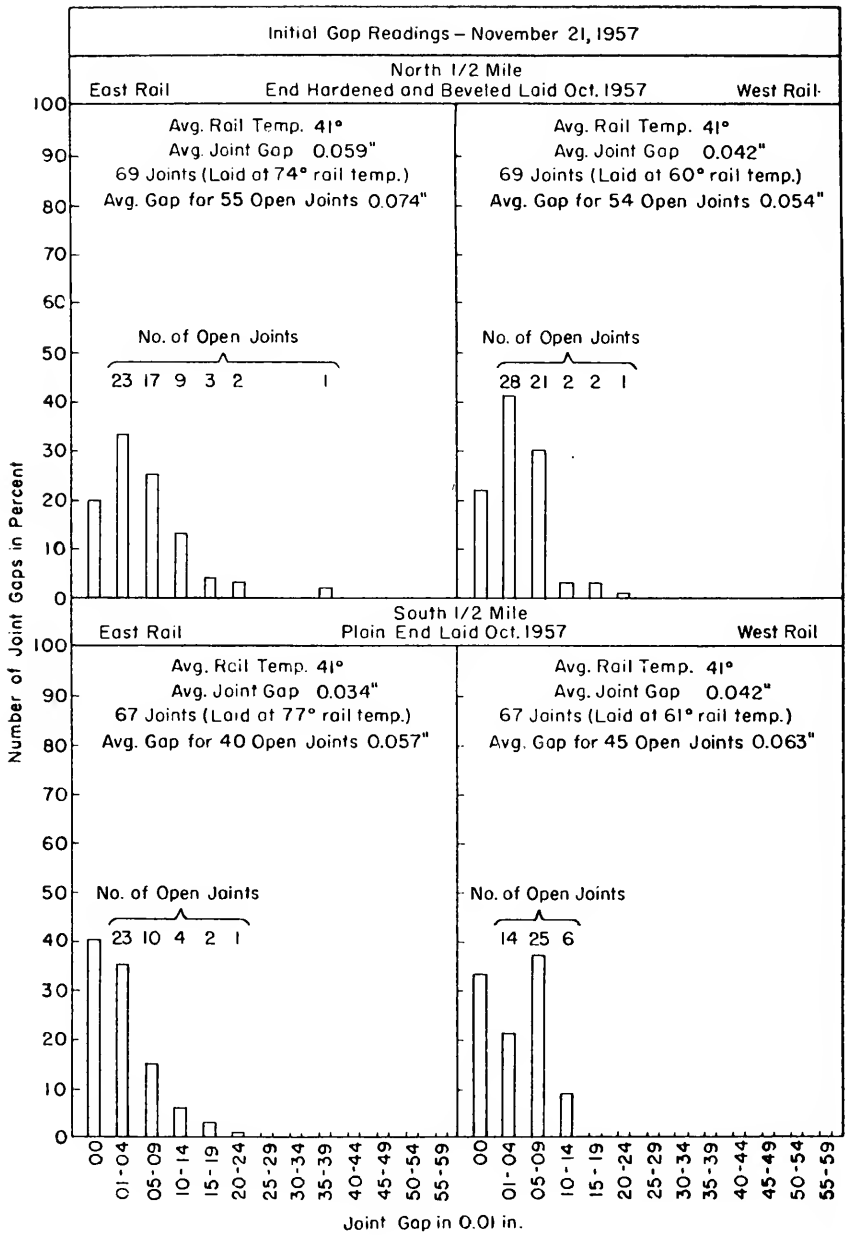
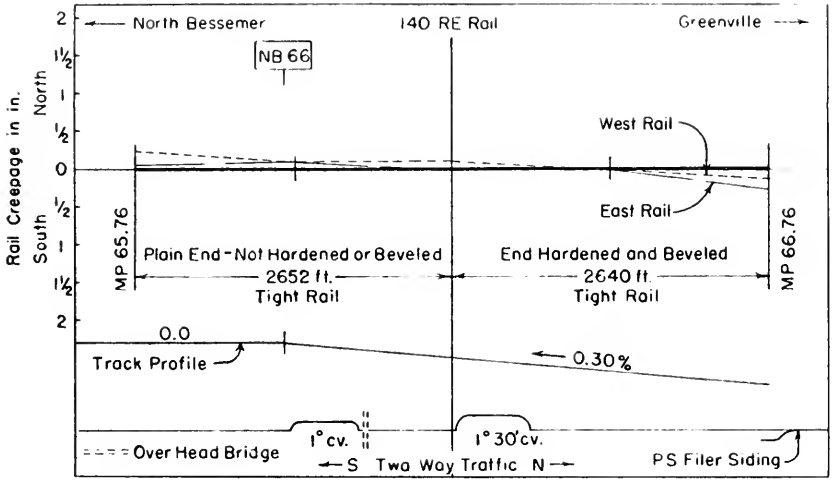


Fig. 16. Joint Gap Measurements in End Hardened and Beveled Rail and Plain End Rail – Not Hardened or Beveled, B & LE RR, near Grove City, Pa.



Note Plain end rail – not hardened or beveled, is anchored with compression clips on every tie, alternately on gage and field side except at joints. End hardened and beveled rail is anchored with Fair anchors both rails, boxed every tie except at joints.

Fig. 17. Rail Creepage, February 10, 1958, B&LE RR, near Grove City, Pa.

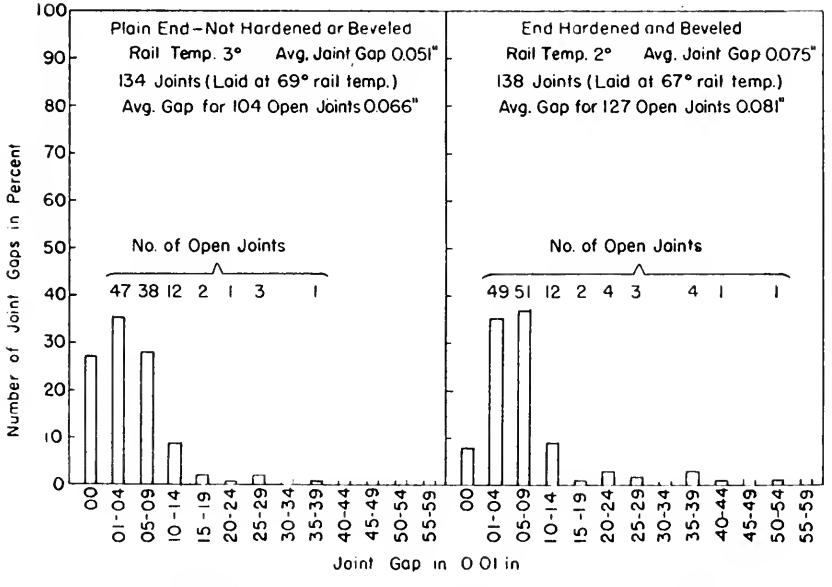


Fig. 18. Joint Gap Measurements for Plain End Rail – Not Hardened or Beveled and End Hardened and Beveled Rail, February 10, 1958, B&LE RR near Grove City, Pa.

A

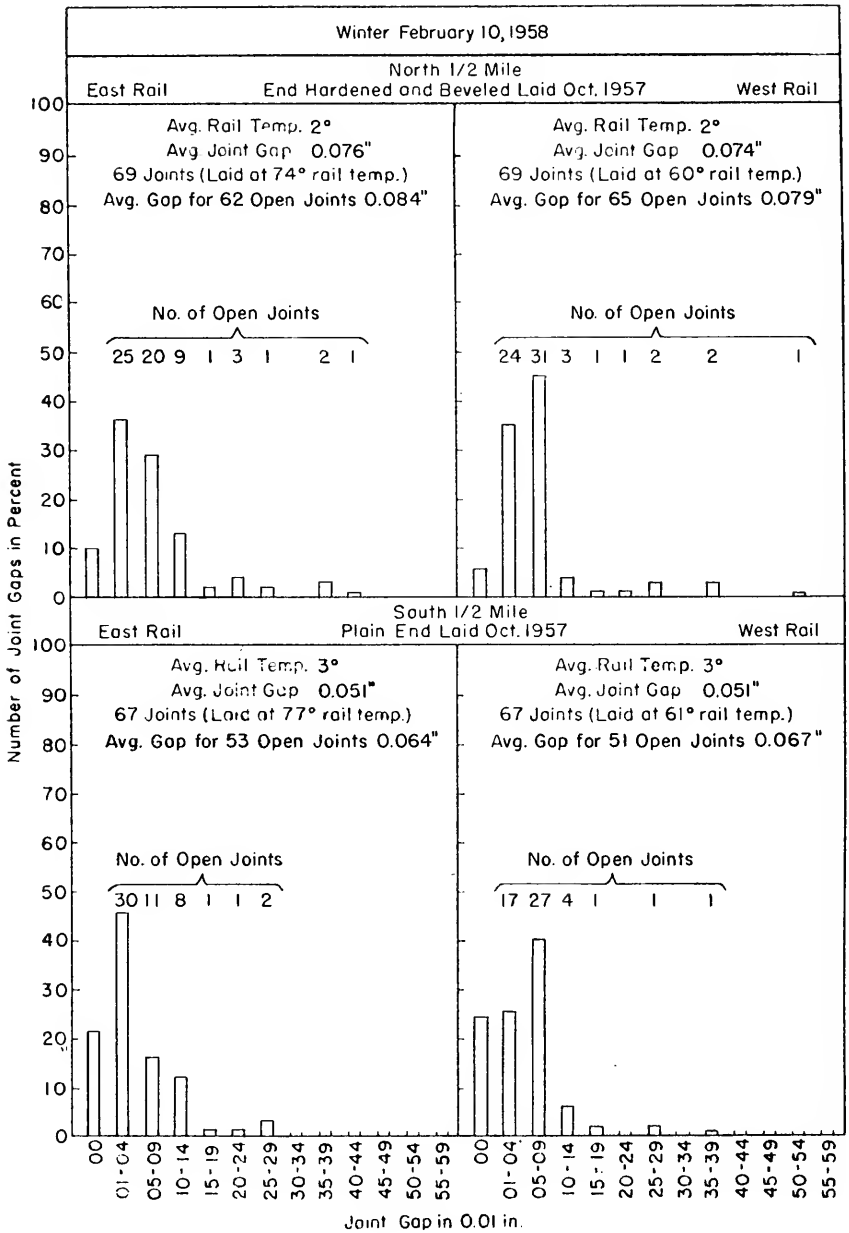
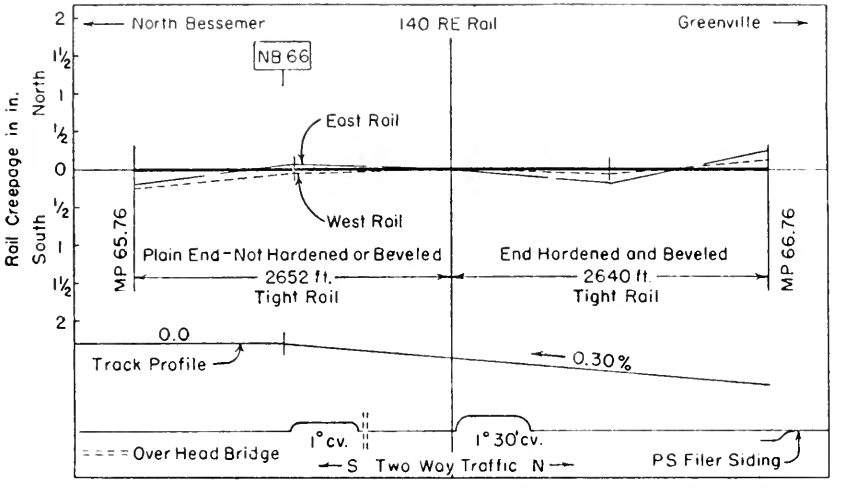


Fig. 19. Joint Gap Measurements in End Hardened and Beveled Rail and Plain End Rail – Not Hardened or Beveled, B&LE RR, near Grove City, Pa.



Note Plain end rail – not hardened or beveled, is anchored with compression clips on every tie, alternately on gage and field side except at joints. End hardened and beveled rail is anchored with Fair anchors both rails, boxed every tie except at joints.

Fig. 20. Rail Creepage, August 11, 1958, B&LE RR, near Grove City, Pa.

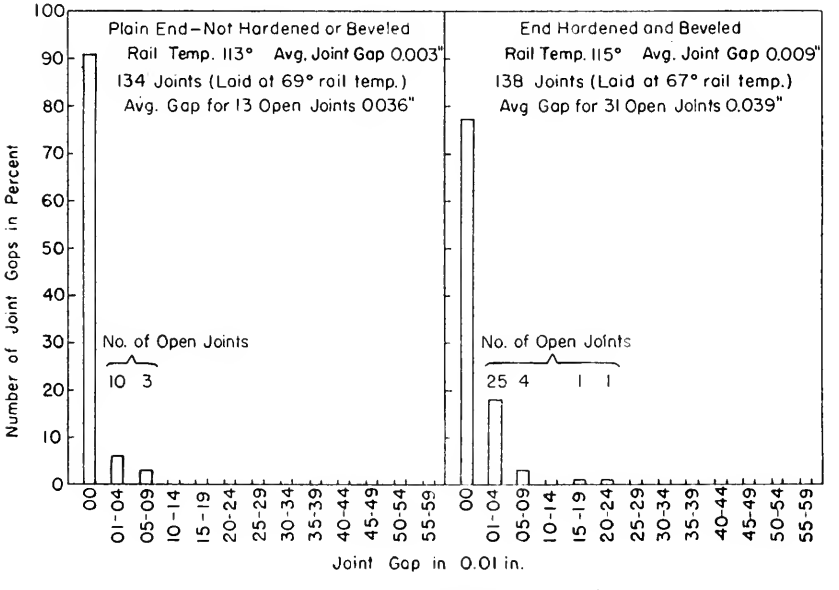


Fig. 21. Joint Gap Measurements for Plain End Rail – Not Hardened or Beveled and End Hardened and Beveled Rail, August 11, 1958
B&LE RR near Grove City, Pa.

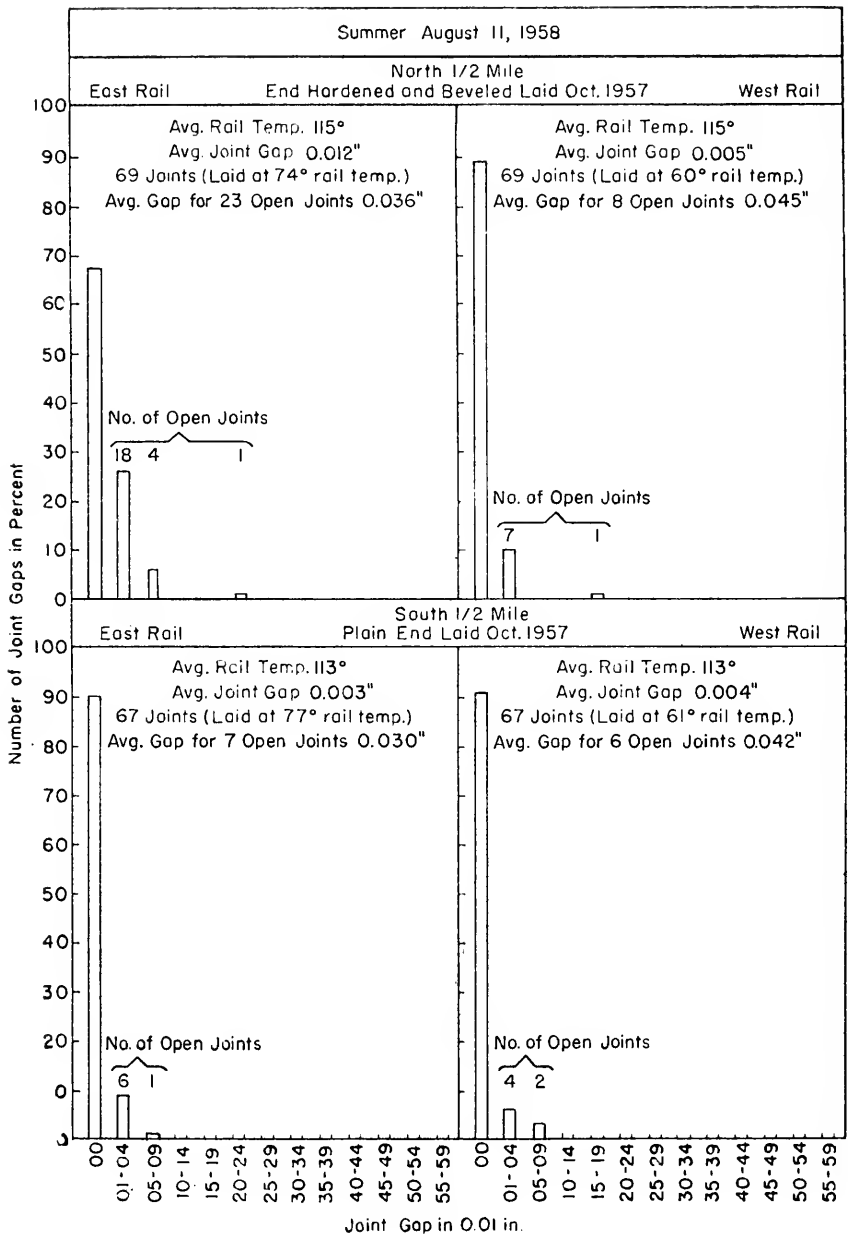
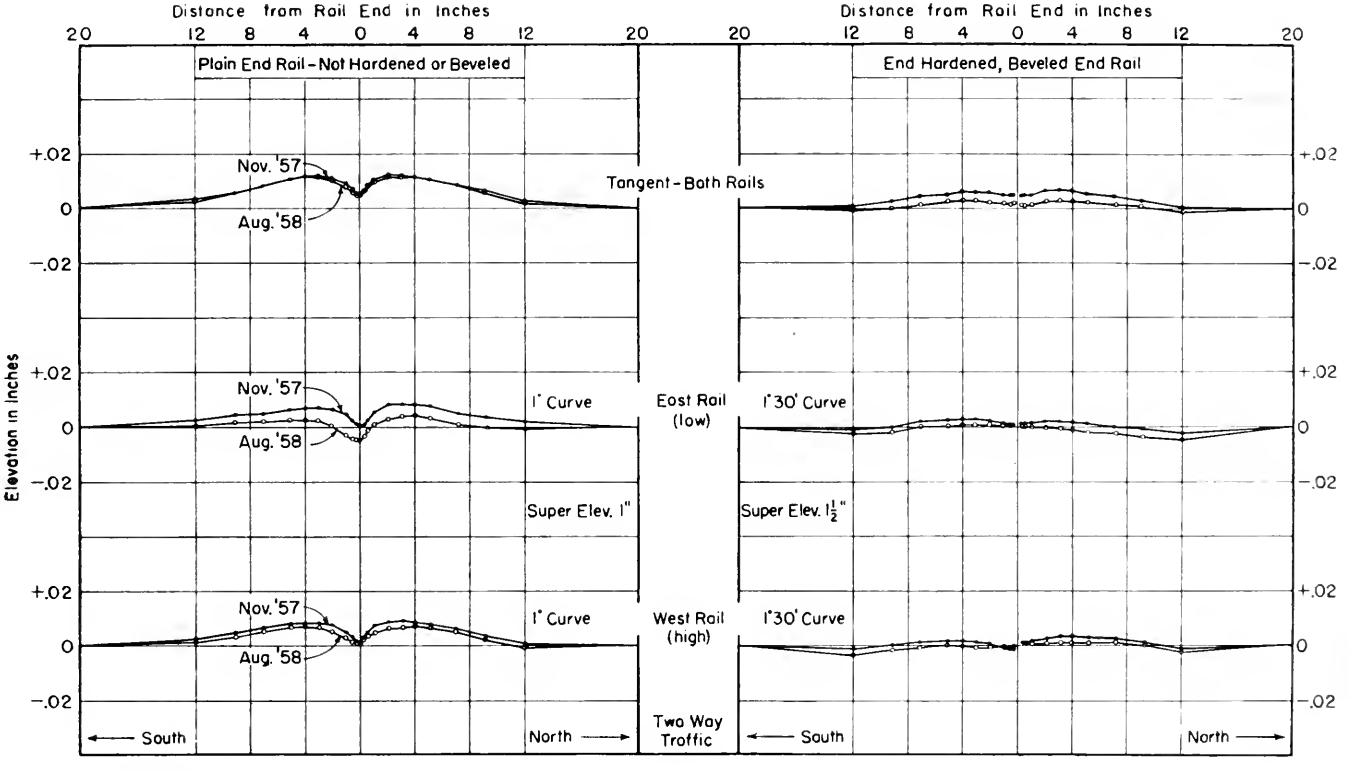


Fig. 22. Joint Gap Measurements in End Hardened and Beveled Rail and Plain End Rail – Not Hardened or Beveled, B & LE RR, near Grove City, Pa.



Note: Profile Elevations: Average of 10 joints each rail.

Fig.23– Rail Surface Profile, Tight Rail, B&LE RR, near Grove City, Pa.

Report on Assignment 10

Methods of Heat Treatment, Including Flame Hardening, of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding

S. H. Poore (chairman, subcommittee), M. C. Bitner, W. E. Cornell, F. W. Creedle, R. M. Frey, W. E. Griffiths, M. J. Hassan, A. E. Haywood, C. C. Herrick, L. H. Jentoft, C. H. Johnson, T. R. Klingel, R. E. Kuston, L. W. Leitze, E. J. Lisy, Jr., H. B. Orr, C. E. Peterson, J. M. Salmon, Jr., R. D. Simpson, T. R. Snodgrass, J. B. Taylor, R. E. Tew, K. H. Von Kampen, Troy West, D. J. White, I. V. Wiley.

This is a progress report, presented as information.

The wording of the committee's assignment quoted above indicates that bolted rail frogs and split switches constitute the basic items of track material for study under it. Up to and including this report, research has been confined to the study of railroad crossing frog construction. At the meeting of the subcommittee held in July 1958, it was decided that, in general, the principles involved in the repair of frogs and switches by welding could be explored through research in crossing panels, and that the subcommittee should undertake to place the relative importance of bolted rail frogs, split switches and crossings in their proper perspective. It was the opinion of the subcommittee that turnout frogs and switches, being of so much greater magnitude than crossing frogs investment-wise, some survey of this field should be made to determine the use of heat-treatment and the various methods of repair by welding so that a proper appraisal could be made of the problem.

To do this, the subcommittee voted to circularize the member railroads of the Association with an appropriate questionnaire. As of this writing the questionnaire had not been distributed.

The following is a description of the work on the simulated crossing panels on the Milwaukee Road at Mannheim, Ill., together with research data accumulated since the last report.

Service Tests of Simulated Crossing Units in the Milwaukee Railroad at Mannheim, Ill.

Foreword

This installation, consisting of 24 test units, is described in the Proceedings, Vol. 56, 1955, page 878. Subsequent reports in Vol. 57, 1956, pages 768 to 774, Vol. 58, 1957, pages 903 to 950 and Vol. 59, 1958, pages 1076 to 1086, cover results of service test from April 13, 1954, to May 31, 1957, involving 82 million gross tons of traffic. Following the measurements taken on May 31, 1957, plans for welding were made, and the welding was performed September 9–11, 1957. A typical panel of bolted rail construction made of the 132 RE section, of which there are three, comprised of eight units each of simulated crossing flangeway intersections, is shown in Fig. 1.

The investigation is being conducted by the AAR research staff under the general direction of G. M. Magee, director of engineering research. H. E. Durham, research engineer track, is in direct charge, assisted by members of his staff.

Maintenance of Units, Including Welding

Following the original installation of the units in April 1954, the first grinding of the tread corners was done in 1955, with heaviest grinding being necessary on the

unhardened units. Subsequent grinding was needed in May 1956 and again in July 1957, at which times the greater flow was on easer rails due to false flanges of tread-worn wheels. Grinding was also necessary on the gage side of the running rails on some of the receiving arms and from between the running rail and the easer rail.

Welding of the 24 units carried out on September 9–11, 1957, was not required as a matter of mainterance, but was done to expedite one of the most important phases of the assignment. The details of the welding were described in Vol. 59, 1958, pages 1083 to 1086. Table 2 of this report describes the material used and welding procedures followed.

Following the completion of the welding, the units were ground to restore, as nearly as possible, the normal rail heights and surface contours. Subsequent grinding was done out-of-face on November 6, 1957, January 14, 1958, and June 4, 1958, to prevent chipping due to excessive flow, primarily on the easer rails. Units showing the greatest need for grinding have been: C–V east and center panels, BS Co. east panel, RA east panel, P–M east panel and OH center panel. The easer rails have exhibited more lipping than the running rails as was the case after the units were installed in 1954.

Rail Wear, Batter and Brinell Hardness

Table 1 in four parts shows the results of test measurements in each of the panels, including reference to the welding procedures shown in Table 2. Inasmuch as a new test cycle commenced with the welding in September 1957, Table 1 does not include wear or batter prior to the 1957 dates indicated. The normal rail wear in the period of approximately one year was similar to that for like test periods.

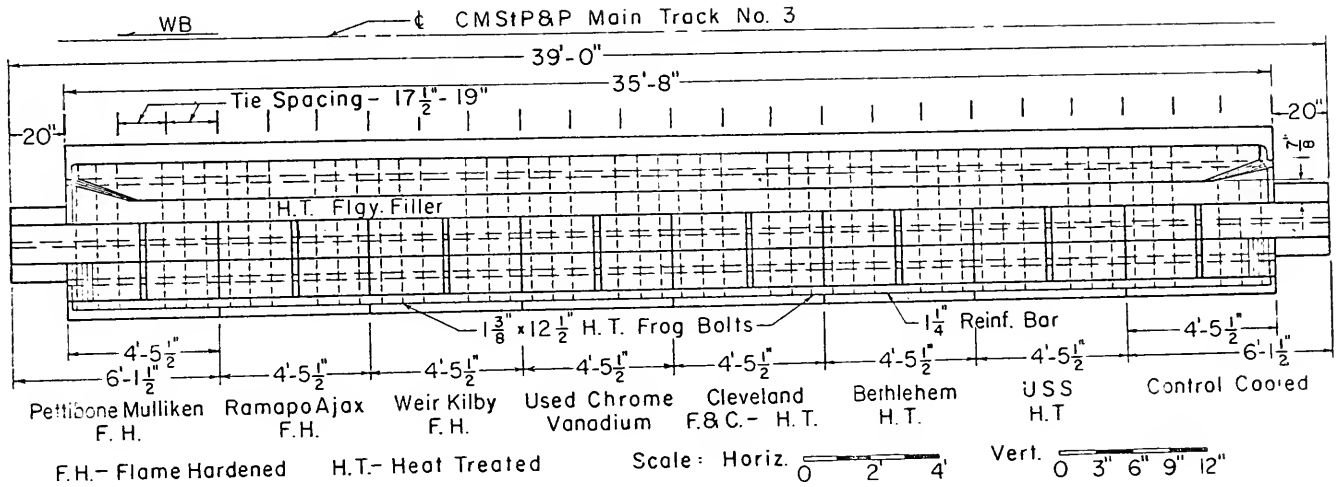
The test period September 1957 to June 1958, involving 28 million gross tons of traffic, is not sufficient to draw any conclusions from the receiving corner batter shown in the tables. All units are holding up well to date, but the OH CC unit in the east panel and the C–V unit in the west panel appear, from visual inspection, to be doing an outstanding job. There has been some chipping of the easer rail of the C–V unit in the west panel, which may indicate too high Brinell hardness, but to date the running rail shows no signs of failure.

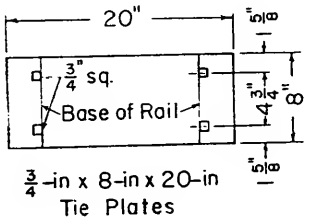
The Brinell hardness of the normal rail surface changed very slightly in the service period covered by this report. The values recorded for the flangeway corners appear rather inconsistent in some instances, but in the brief test period of less than nine months it would be difficult to make a worthwhile appraisal of the variations.

Another year of service with continued heavy tonnage should permit some evaluation of welding techniques, although it now appears that good results will be obtained from a majority of the welds.

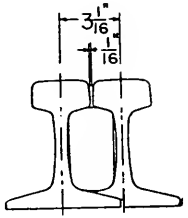
Acknowledgement

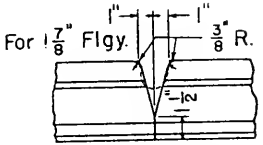
The Association appreciates the cooperation of the Milwaukee Road and the suppliers in conducting the investigation during the past year.





¾-in x 8-in x 20-in Tie Plates





Detail of Running Rail Flangeway
(Easer rails were not cut in two.)

Note: Ramapo A ax units had flangeway conto similar to s ape of 132 RE rail head.

Fig. 1. Plan of One Panel of Eight Units of Simulated 132 RE Bolted Rail Crossing Flangeway Intersections at Mannheim, Illinois.

TABLE 1. PART 1. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS

WEST PANEL Test period, May 31, 1957 through June 19, 1958

Designation of Unit	Welding Procedure*	Location	Rail Head Wear and Batter			Brinell Hardness				
			Avg. Normal Wear in.	Wear Plus Batter in.	Batter Only in.	Initial Before Traffic	After First Welding 9-11-57	6-19-58	Increase	
									Normal	F. W. Corner
Flame Hardened Rail										
Pettibone Mulliken Corporation	4E	Avg. Both Ends	.006			312		368	56	
		Rec. Cor.		.029	.023		302	340		38
		Lv. Cor.		.024	.018		321	351		30
Ramapo Ajax Div. American Brake Shoe Company	3E	Avg. Both Ends	.004			360		415	55	
		Rec. Cor.		.035	.031		327	321		-6
		Lv. Cor.		.015	.011		337	361		24
Weir-Kilby	3E	Avg. Both Ends	.004			328		384	56	
		Rec. Cor.		.049	.045		382	371		-11
		Lv. Cor.		.017	.013		321	335		14
Heat Treated Rail										
Cleveland Frog and Crossing Company	3E	Avg. Both Ends	.006			339		380	41	
		Rec. Cor.		.036	.030		351	335		-16
		Lv. Cor.		.019	.013		332	364		32
Bethlehem Steel Company	4E	Avg. Both Ends	.006			340		378	38	
		Rec. Cor.		.036	.030		340	337		-3
		Lv. Cor.		.022	.016		311	321		10
United States Steel Corporation	4E	Avg. Both Ends	.005			310		367	57	
		Rec. Cor.		.051	.046		332	323		-9
		Lv. Cor.		.010	.005		332	321		-11
Other Rails										
Used Chrome-Vanadium Rail	7AE	Avg. Both Ends	.006			366		374	8	
		Rec. Cor.		.032	.026		438	444		6
		Lv. Cor.		.024	.018		387	366		-21
C. C. Blue End Rail as Rolled	6E	Avg. Both Ends	.006			256		298	42	
		Rec. Cor.		.046	.040		266	332		66
		Lv. Cor.		.024	.018		252	327		75

* See Table 2 for description of the Welding Procedures

TABLE 1. PART 2. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS.

CENTER PANEL Test period, May 31, 1957 through June 19, 1958

Designation of Unit	Welding Procedure	Location	Rail Head Wear and Batter			Brinell Hardness				
									Increase	
			Avg. Normal Wear in.	Wear Plus Batter in.	Batter Only in.	Initial Before Traffic	After First Welding 9-11-57	6-19-58	Normal	F. W. Corner
Flame Hardened Rail										
Pettibone Mulliken Corporation	3E	Avg. Both Ends	.004			312		366	54	
		Rec. Cor.		.040	.036		302	338		36
		Lv. Cor		.011	.007		311	337		26
Ramapo Ajax Div. American Brake Shoe Company	2G	Avg. Both Ends	.004			338		388	50	
		Rec. Cor.		.036	.032		347	338		-9
		Lv. Cor.		.014	.010		364	356		-8
Weir-Kilby	1E	Avg. Both Ends	.006			321		374	53	
		Rec. Cor.		.055	.049		359	368		9
		Lv. Cor.		.015	.009		269	351		82
Heat Treated Rail										
Cleveland Frog and Crossing Company	1E	Avg. Both Ends	.004			336		375	39	
		Rec. Cor.		.046	.042		293	364		71
		Lv. Cor.		.023	.019		217	364		147
Bethlehem Steel Company	3E	Avg. Both Ends	.006			337		384	47	
		Rec. Cor.		.045	.039		340	342		2
		Lv. Cor.		.015	.009		321	359		38
United States Steel Corporation	3E	Avg. Both Ends	.006			338		379	41	
		Rec. Cor.		.048	.042		359	377		18
		Lv. Cor.		.018	.012		321	361		40
Other Rails										
Used Chrome-Vanadium Rail	2AG	Avg. Both Ends	.004			362		378	16	
		Rec. Cor.		.044	.040		266	313		47
		Lv. Cor.		.010	.006		332	319		-13
C. C. Blue End Rail as Rolled	2G	Avg. Both Ends	.006			252		291	39	
		Rec. Cor.		.046	.040		302	315		13
		Lv. Cor.		.010	.004		340	364		24

TABLE 1. PART 3. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS

EAST PANEL Test period, May 31, 1957 through June 19, 1958

Designation of Unit	Welding Procedure	Location	Rail Head Wear and Batter			Brinell Hardness				
			Avg. Normal Wear in.	Wear Plus Batter in.	Batter Only in.	Initial Before Traffic	After First Welding 9-11-57	6-19-58	Increase	
									Normal	F. W. Corner
Flame Hardened Rail										
Pettibone Mulliken Corporation	1G	Avg. Both Ends	.004			296		346	50	
		Rec. Cor.		.037	.033		302	319		17
		Lv. Cor.		.010	.006		302	321		19
Ramapo Ajax Div. American Brake Shoe Company	1G	Avg. Both Ends	.004			344		389	45	
		Rec. Cor.		.049	.045		327	338		11
		Lv. Cor.		.011	.007		302	317		15
Wēir-Kilby	1G	Avg. Both Ends	.004			303		365	62	
		Rec. Cor.		.061	.057		317	302		-15
		Lv. Cor.		.015	.011		321	315		-6
Heat Treated Rail										
Cleveland Frog and Crossing Company	2G	Avg. Both Ends	.004			329		376	47	
		Rec. Cor.		.040	.036		351	332		-19
		Lv. Cor.		.013	.009		347	423		76
Bethlehem Steel Company	1G	Avg. Both Ends	.006			353		384	31	
		Rec. Cor.		.042	.036		262	306		44
		Lv. Cor.		.012	.006		293	298		5
United States Steel Corporation	2G	Avg. Both Ends	.006			304		364	60	
		Rec. Cor.		.035	.029		321	315		-6
		Lv. Cor.		.008	.002		387	423		36
Other Rails										
Used Chrome-Vanadium Rail	1AG	Avg. Both Ends	.005			361		378	17	
		Rec. Cor.		.048	.043		286	306		20
		Lv. Cor.		.010	.005		259	309		50
C. C. Blue End Rail as Rolled	1G	Avg. Both Ends	.006			246		294	48	
		Rec. Cor.		.027	.021		293	284		-9
		Lv. Cor.		.012	.006		293	300		7

TABLE 1. PART 4. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS

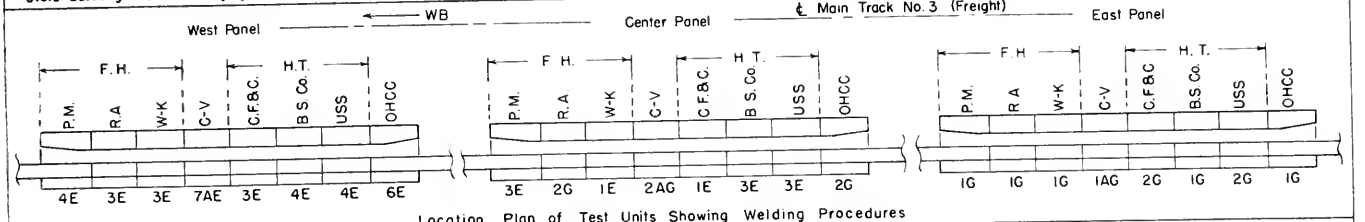
AVG. OF 3 PANELS — Test Period May 31, 1957 through June 19, 1958

Designation of Unit	Location	Rail Head Wear and Batter			Brinell Hardness				
								Increase	
		Avg. Normal Wear in.	Wear Plus Batter in.	Batter Only in.	Initial Before Traffic	After First Welding 9-11-57	6-19-58	Normal	F. W. Corner
Flame Hardened Rail									
Pettibone	Avg. Both Ends	.005			307		360	53	
Mulliken	Rec. Cor.		.035	.030		302	332		30
Corporation	Lv. Cor.		.015	.010		311	336		25
Ramapo Ajax Div.	Avg. Both Ends	.004			347		397	50	
American Brake	Rec. Cor.		.040	.036		334	332		-2
Shoe Company	Lv. Cor.		.013	.009		334	345		11
Weir-Kilby	Avg. Both Ends	.005			317		374	57	
	Rec. Cor.		.055	.050		353	347		-6
	Lv. Cor.		.016	.011		304	334		30
Heat Treated Rail									
Cleveland Frog	Avg. Both Ends	.005			335		377	42	
and Crossing	Rec. Cor.		.041	.036		332	344		12
Company	Lv. Cor.		.019	.014		299	384		85
Bethlehem Steel	Avg. Both Ends	.006			343		382	39	
Company	Rec. Cor.		.041	.035		314	328		14
	Lv. Cor.		.016	.010		308	326		18
United States Steel	Avg. Both Ends	.006			317		370	53	
Corporation	Rec. Cor.		.045	.039		337	338		1
	Lv. Cor.		.012	.006		347	368		21
Other Rails									
Used Chrome-	Avg. Both Ends	.005			363		377	14	
Vanadium Rail	Rec. Cor.		.041	.036		330	354		24
	Lv. Cor.		.015	.010		326	331		5
C. C. Blue End	Avg. Both Ends	.006			251		294	43	
Rail as Rolled	Rec. Cor.		.040	.034		287	310		23
	Lv. Cor.		.015	.009		295	330		35

Notes: All rail height measurements and Brinell readings were taken on the longitudinal center line of the running rail. The data taken 10 in. from both ends of each unit were used for determining the normal head wear and work hardening of the running rail. Rail head wear and batter of the tread corners were based on the readings taken 3/4 in. from the adjacent side of each flangeway. Values of batter of the tread corners cover the period from September 11, 1957 through June 19, 1958 for a gross tonnage of 28 million. Total tonnage for the 4.2 year service period is 119 million. See Table 2 for description of the welding procedures. See Vol. 59, 1958, pages 1079-1082 for the test period prior to the first welding.

TABLE 2. WELDING PROCEDURES FOR REPAIRING SIMULATED CROSSING UNITS ON THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS

(1). Pregrinding for all welding. Remove defective metal by grinding. (2). Finishing. Peen all gas welds while hot and finish by grinding after post heating if required when metal is cold. In electric welding lightly peen beads as deposited and finish by grinding after welding or post heating when the metal is cool. Care should be exercised to avoid burning the steel by grinding.



Location Plan of Test Units Showing Welding Procedures

Welding Procedure	Preheating	Description of Welding Rods	Post Treatment
1G (a)	None	AIRCO RR rod, bare (Use 5%-10% carburizing flame)	None
1AG	do	do	Post-heat to 1000° F for 20 minutes
2G (a)	None	Oxweld M.W. rod, bare	None
2AG	do	do	Post-heat to 1000° F for 20 minutes
1E	Preheat to 350° F for 10 minutes	AIRCO No. 361 coated electrode	None
3E	Preheat to 500° F in temperate weather and to 550° F in cold weather	Teleweld Cro-Moly-Mang electrode Type 16 coating (GE S-32)	Post-heat to 800° F. Air cool in temperate weather Blanket in cold or cool windy weather
4E	Preheat to between 300° F and 400° F	A. O. Smith Diamond-Weld A electrode	Post-heat to 700° - 800° F as soon as welding is completed
6E	Preheat to 400° F	McKay E-973 coated electrode	None
7AE	Preheat to 500° - 600° F	National Cyl. Gas Co. No. 170 RR rod with International Rail Weld Corp. coating	Post-heat with torch 20 minutes to 1000° F

Notes: P. M. = Pettibone Mulliken Corp. R.A. = Romapo Ajax Division. W-K = Trackwork Division, Taylor-Wharton Iron & Steel Corp C-V = Chrome-Vanadium alloy steel. C. F. & C. = Cleveland Frog & Crossing Co. B. S. Co. = Bethlehem Steel Company. USS = United States Steel Corp. OHCC = Open hearth control cooled rail, as rolled. F.H. = Flame hardened rail. H.T. = Heat treated rail.
All rail temperatures are to be checked with Tempilstiks and recorded.
(a). When gas welding heat treated and flame hardened units, avoid overheating the base metal and apply the weld metal in small patches on the tread corners.

Report on Assignment 11

Economies to be Gained by the Railroads From the More Extensive Use of AREA Trackwork Plans

W. R. Bjorklund (chairman, subcommittee), W. E. Cornell, Troy West, J. E. Armstrong, Jr., R. D. Baldwin, M. C. Bitner, R. J. Bruce, K. E. Dunn, C. R. Fears, J. W. Fulmer, A. B. Hillman, C. H. Johnson, R. J. D. Kelly, J. S. Parsons, G. R. Sproles, M. J. Zeeman.

Your committee submits the following final report, presented as information.

Economies are the primary purpose for adopting standards; their development stems from the need for simpler and cheaper methods for performing an operation. The standard will be accepted if it performs the function well. The development of a standard depends on the concerted efforts of individuals, thoroughly experienced in the problem at hand, working as a group. Such a group of men is available in the AREA, and its recommendations for trackwork plans should be satisfactory for all railroads.

Large-scale production of a standardized item will result in economy. It is obvious that volume production of a particular item will result in a lower unit cost compared with small runs of many different designs only slightly at variance with each other Retooling costs are saved as well as the expenses of training personnel in handling the different designs. All branches of the railroads are becoming increasingly more conscious of the need for standardization in the interest of economy.

The most feasible time for a railroad to adopt a standardized set of trackwork plans would be with the adoption of a new rail section. Inasmuch as new rail sections have been adopted periodically by the AREA and the various railroads on this continent, it behooves each railroad to seriously consider adopting an AREA recommended section when a new section is desired. Another practical method for standardization would be to purchase new turnout material in a few basic rail sections, replacing turnouts complete and using the lighter material released for repair work. The turnout plans of many railroads are so slightly at variance with current AREA standards that there would be little difficulty in making a change.

The advantages of standardizing turnout material are as follows:

1. *Design*
   a. Eliminate expense of design plans.
   b. Better product due to industry-wide focus
   c. Reduce tendency for inconsequential revisions.
   d. Require industry approval for revision.
   e. Simplify railroads plant inspection.
2. *Placing Orders*
   a. Obtain bids quicker.
   b. Keener competition.
3. *Manufacturing*
   a. Mass-production techniques in shops.
   b. Stockpile at shops for stable business cycle.
   c. Reduce inventory of special plates, etc.
   d. Reduce supervision in shops.
   e. Save on manufacturer's engineering costs.
   f. Reduce manufacturer's labor turnover.

4. Inventory

a. Better delivery from manufacturer.
b. Deliveries direct to job when required.
c. Reduce store stock on railroads.

5. Miscellaneous

a. Cost of turnout material will be reduced.
b. Coordinate delivery with track work program.
c. Borrow from neighboring railroad.
d. Nation-wide testing ground for materials.

Your committee feels that the greatest economy can be achieved if a set of recommended plans for the Portfolio of Trackwork Plans can be developed that would eliminate all alternates which affect the shop work. Alternates should be indicated only for parts not basic to manufacturer of turnout material.

Report of Committee 4—Rail

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W. J. Cruse,
Vice Chairman,
A. P. Talbot, *Secretary,*
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H. F. Whitmore
R. P. Winton
Edward Wise, Jr.
J. E. Yewell
W. L. Young

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions ..... page 874

2. Collaborate with AISI Technical Committee on Rail and Joint Bars in research and other matters of mutual interest.

   Progress report, including as Appendix 2–a, Report on Investigation of Failures in Control-Cooled Railroad Rails ..... page 878

3. Rail failure statistics, covering (a) all failures; (b) transverse fissures; (c) performance of control-cooled rail.

   Progress report, including statistics on rail failures reported up to December 31, 1597 (on net ton basis) ..... page 883

4. Rail end batter, causes and remedies.

   Progress report, presented as information ..... page 903

5. Economic value of various sizes of rail.

   Progress report, presented as information ..... page 903

6. Service tests of various types of joint bars.

   Progress report, presented as information ..... page 905

7. Joint bar wear and failures; revision of design and specification for new bars, including insulated joints, and bars for maintenance repairs.

Progress report, presented as information ..... page 916

8. Causes of shelly spots and head checks in rail; methods for their prevention.

Progress report, presented as information ..... page 916

Appendix 8–a—Report on service tests of heat-treated and alloy-steel rails ..... page 919

Appendix 8–b—Final report on service tests of 155-lb heat-treated rail on Pennsylvania Railroad ..... page 930

Appendix 8–c—Report on shelly rail studies at University of Illinois ... page 941

Appendix 8–d—Investigation into significance of the hydrogen level in rail steel ..... page 949

Appendix 8–e—Final report on a three-dimensional photoelastic investigation of the stress distribution in the head of a model of a railroad rail along lines parallel to the axis of the rail ..... page 951

9. Recent developments affecting rail section.

Progress report, presented as information ..... page 970

10. Service performance and economics of 78-ft rail, collaborating with Committee 5; specifications for 78-ft rail.

Progress report, presented as information ..... page 972

11. Rail damage resulting from engine burns; prevalence; means of prevention; repair by welding.

Brief progress report, presented as information ..... page 975

THE COMMITTEE ON RAIL,
L. S. CRANE, *Chairman.*

AREA Bulletin 549, February 1959.

Report on Assignment 1

Revision of Manual

W. J. Cruse (chairman, subcommittee), L. S. Crane, V. E. Hall, W. H. Hobbs, H. S. Loeffler, Ray McBrian, G. L. P. Plow, R. B. Rhode, S. R. Shepley, J. S. Wearn, H. F. Whitmore, Edward Wise, Jr.

Your committee submits the following revisions with the recommendation that they be adopted and published in the Manual:

Page 4–1–13

Fig. 8—Recommended Head Easement for Joint Bars.

Delete, substituting new drawing presented herewith.

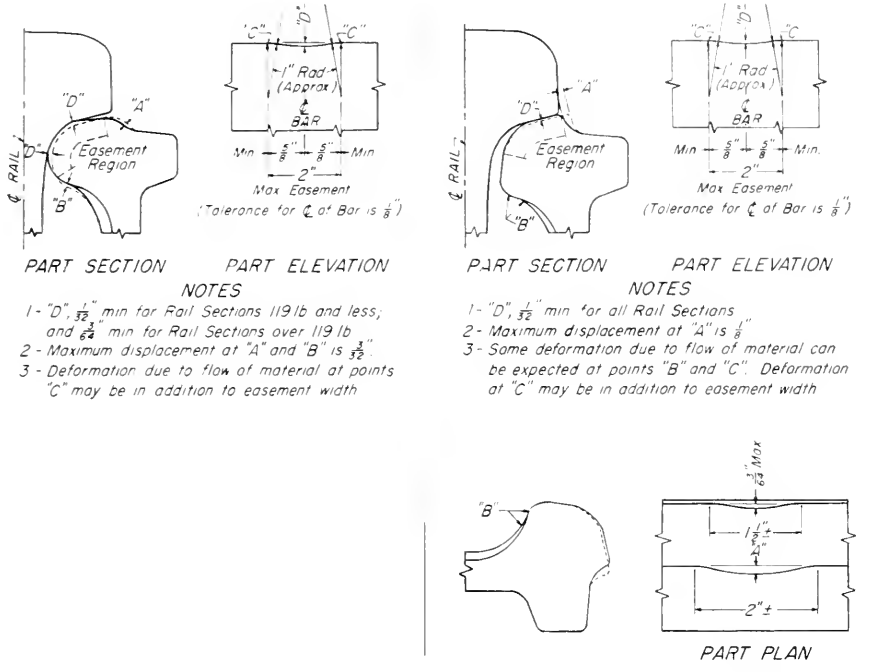

Fig. 8—Recommended head easement for joint bars.

Pages 4–3–1 to 4–3–14, incl.

RAIL RECORD FORMS

Page 4–3–7. Report of Rail Failures in Main Track, Form 402–A. Reapprove with the following revisions:

Add in the upper right hand corner the following in a "box":

Div. .....
Dist. .....
Section .....
Location: M.P. ..... Plus ..... Ft.
Nearest Station .....
Signal Number .....

Add the following note to the left of the above "box":

Block out on copy accompanying accident report to ICC

Under the foregoing note, add a space, underlined, followed by the word "Railroad."

Eliminate the following words on first line of present form: Div., Dist., Section.

Eliminate present questions 3 and 4.

Revise numbers of questions 5 through 11, as follows:

5	to	read	3
6	"	"	4
7	"	"	5
8	"	"	6
9	"	"	7
10	"	"	8
11	"	"	9

Eliminate present question 12.

Revise numbers of questions 13 through 22, as follows:

13	to	read	10
14	"	"	11
15	"	"	12
16	"	"	13
17	"	"	14
17a	"	"	15
18	"	"	16
19	"	"	17
20	"	"	18
21	"	"	19
22	"	"	20

Revise question 23 to read 21 and add to (a) the words: "and whether break or defect is over or between ties."

Under Instructions, add to "B": "also secondary or running tracks, the use of which is controlled by operator or dispatcher".

Eliminate present instruction "C" and reletter the succeeding instructions as follows: Change present instructions "D" to "C", "E" to "D" and add instruction "E", as follows: "Under question 17 report any welding or heating at or near point of failure; whether shop butt weld, field butt weld, field end hardening, field building up of rail end, building up of driver burn, or other field weld. State which."

On the back side of Form 402–A, delete the definition of Detail Fracture, including paragraphs (1) and (2), and substitute the following:

DETAIL FRACTURE.—A progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures, or other defects which have internal origins. Detail fractures may arise from shelly spots, head checks or flaking.

Add definitions for shelly spots, head checks, and flaking, as follows:

SHELLY SPOTS.—Where a thin (usually 3/8-in. in depth or less) shell-like piece of surface metal becomes separated from the parent metal in the rail head, generally at the gage corner. See Fig. 7. It may be evidenced by:

(a) A black spot appearing on the rail head over the zone of separation.
(b) A piece of metal breaking out completely, leaving a shallow cavity in the rail head.

In the case of a small shell there may be no surface evidence, the existence of the shell being apparent only after the rail is broken or sectioned.

HEAD CHECKS.—Hair-line cracks which appear in the gage corner of the rail

head, at any angle with the length of the rail. When not readily visible the presence of the check may often be detected by the raspy feeling of their sharp edges. See Fig. 8.

FLAKING.—Where small shallow flakes of surface metal, generally not more than ¼ in. in length or width, break out of the gage corner of the rail head.

Page 4–3–12. Annual Report of Progressive Type Head Failures in Rail of All Ages, Made by All Processes, Form 402–L. Reapprove this form with the following revisions: Delete the first line under Detected Failures, which reads: "Transverse Fissures verified by breaking", and change the next line to read: "All Transverse Defects, including Transverse Fissures, Compound Fissures, and Detail Fractures."

Report on Assignment 2

Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest

L. S. Crane (chairman, subcommittee), G. V. Begany, Jr., J. A. Bunjer, C. J. Code, C. A. Colpitts, W. J. Cruse, W. H. Hobbs, J. C. Jacobs, W. M. Jaekle, K. K. Kessler, Ray McBrian, B. R. Meyers, L. T. Nuckols, Embert Osland, R. P. Winton.

This committee sponsors studies conducted at the University of Illinois under the direction of Professor R. E. Cramer, who, under Appendix 2–a following, presents his annual report on investigation of failures in control-cooled rails.

Research work on shelly rail studies, hydrogen content of rail steel, and photoelastic stress studies is presented as a part of the report on Assignment 8.

In cooperation with the manufacturers, an improved nomenclature to describe various types of rail failures has been developed and will be progressed as a part of Assignment 1.

Other items are now under study, including the use of radio-isotopes to investigate "shelly spots" in rail steel, chamfering and peening of bolt holes, and standardization of rail sections.

Appendix 2–a

Investigation of Failures in Control-Cooled Rails

By R. E. Cramer

Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgement

This investigation is financed equally by the Association of American Railroads and the American Iron and Steel Institute. Student assistants Robert B. Hogue and Ray A. Dahman worked on this investigation on a part-time basis.

Control-Cooled Rails Which Failed in Service

Since the last report on October 1, 1957, reports have been prepared on 25 failed control-cooled rails. These reports go to the railroad engineers supplying the failed rails and copies go to the rail manufacturer and the director of engineering research, AAR, for the Association's rail failure statistics.

Table 1 gives a summary of the 25 failures and Table 2 lists each rail separately.

Table 1—Summary of Failed Control-Cooled Rails

Transverse fissures from shatter cracks	2
Transverse fissures from hot torn steel	6
Transverse fissure from slag inclusion	1
Engine burn fracture	1
Base break at seam	1
Detail fracture from shelling	8
Fractured base	1
Bolt hole break	1
Fracture at welded engine burn	2
Vertical split head	1
Shelling only	1
Total	25

Transverse Fissures from Shatter Cracks

Only two transverse fissures from shatter cracks were found. These were in rails from the Algoma Mill and were both rolled before its containers were supplied with tight-fitting lids late in 1950.

Transverse Fissures from Hot Torn Steel

Five of the transverse fissures from hot torn steel were from the Steelton Mill, rolled in 1950, 1951, and 1952. The sixth was from the Lackawanna Mill rolled in 1950. Fig. 1 shows fissures and etched slices from failed rails Nos. 973 and 976 which contain numerous holes in the steel. Slice b from rail 973 also shows two other transverse fissures in this rail head.

Transverse Fissure from Inclusion

Failed rail No. 979 is shown in Fig. 2. Part a is a photograph of the 30 percent transverse fissure with a round inclusion as a nucleus. A specimen was cut for metallographic examination and ground down to this nucleus as shown at 6× magnification in Fig. 2b. The large nucleus is at the left end of the specimen. Directly in line with this nucleus is another smaller inclusion. It is shown at 35× magnification in Fig. 2c. These inclusions appeared to be a glassy material like the slag produced in

TABLE 2—FAILED CONTROL-COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1957, AND SEPTEMBER 30, 1958

T. F. = Transverse Fissure; D. F. = Detailed Fracture

Source of Failed Rail	*Lab. Failed Rail Number*	*Size of Rail*	*Mill*	*Heat Number Rail Letter Ingot Number*	*Date Rolled*	*Classification of Failure*
Erie	970	112	E. Thomson	206381-C-32	8–1939	Engine Burn Fracture
CP	971	110	Algoma	3158-A-1	11–1949	T.F. from Shatter Crack
GN	972	115	Lackawanna	9514-A-1	10–1952	Base Break at Seam
B&O	973	140	Steelton	88172-B-15	3–1951	T.F. from Hot Torn Steel
B&O	974	140	Steelton	89194-B-7	4–1952	T.F. from Hot Torn Steel
B&O	975	140	Steelton	85056-C-18	1–1952	T.F. from Hot Torn Steel
B&O	976	140	Steelton	85056-B-9	1–1952	T.F. from Hot Torn Steel
Va	978	131	E. Thomson	0708101-E-18	10–1945	D.F. from Shelling
IC	979	112	Tennessee	812237-G-11	9–1943	T.F. from Slag Inclusion
IC	980	115	Tennessee	836856-E-3	10–1956	Fractured Base
Erie	981	115	E. Thomson	01E389-E-16	8–1950	Bolt Hole Break
C&O	982	132	Lackawanna	4490-A-11	10–1950	T.F. from Hot Torn Steel
C&O	983	131	Inland	38186-C-19	1–1939	Fracture at Welded Engine Burn
Erie	984	115	Inland	36347-H-18	2–1949	Vertical Split Head
CP	985	100	Algoma	7238-C-11	2–1950	T.F. from Shatter Crack
UP	986	133	Colorado		1948	D.F. from Shelling
CP	987	100	Algoma	23259-F-8	10–1939	Fracture at Welded Engine Burn
KCS	988	127	Gary	411800-E-21	11–1946	Shelling only
C of G	989	112	Tennessee	852052-K	1937	D.F. from Shelling
C of G	990	90	Tennessee	832372-H	1943	D.F. from Shelling
C of G	991	112	Tennessee	833209-G-19	1944	D.F. from Shelling
C of G	992	112	Tennessee	865705-E	1941	D.F. from Shelling
B&O	993	140	Steelton	82289-C-17	6–1950	9 T.F. from Hot Torn Steel
Va	994	131	E. Thomson	1011070-E-10	1–1945	2 D.F. from Shelling
CP	995	100	Algoma	1637-A-4	1–1939	D.F. from Shelling

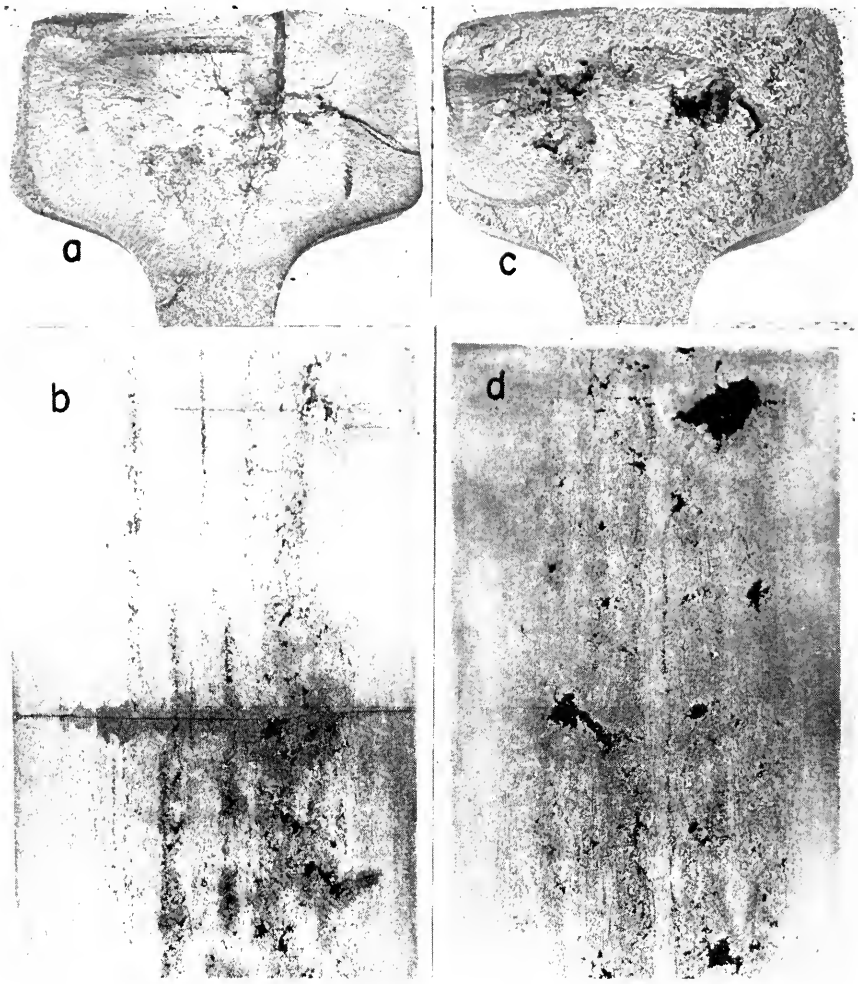

Fig. 1—Two transverse fissures from hot torn steel. Views a and b are rail 973, c and d, rail 975.

open-hearth steelmaking. It should be noted that even with this rather large inclusion in the steel it took 14 years for the transverse fissure to develop.

Vertical Split Head from Rolling Defect

An etched cross section of rail 984 is shown in Fig. 3. This failure is a vertical split head developed from a rolling defect sometimes called a fishtail. This defect is near the bottom end of the bottom rail from the ingot. The rolling defect occurs at this location when most ingots are rolled, but ordinarily the rails are cropped back far enough to eliminate the lapped or fishtail condition. In this case it was not all

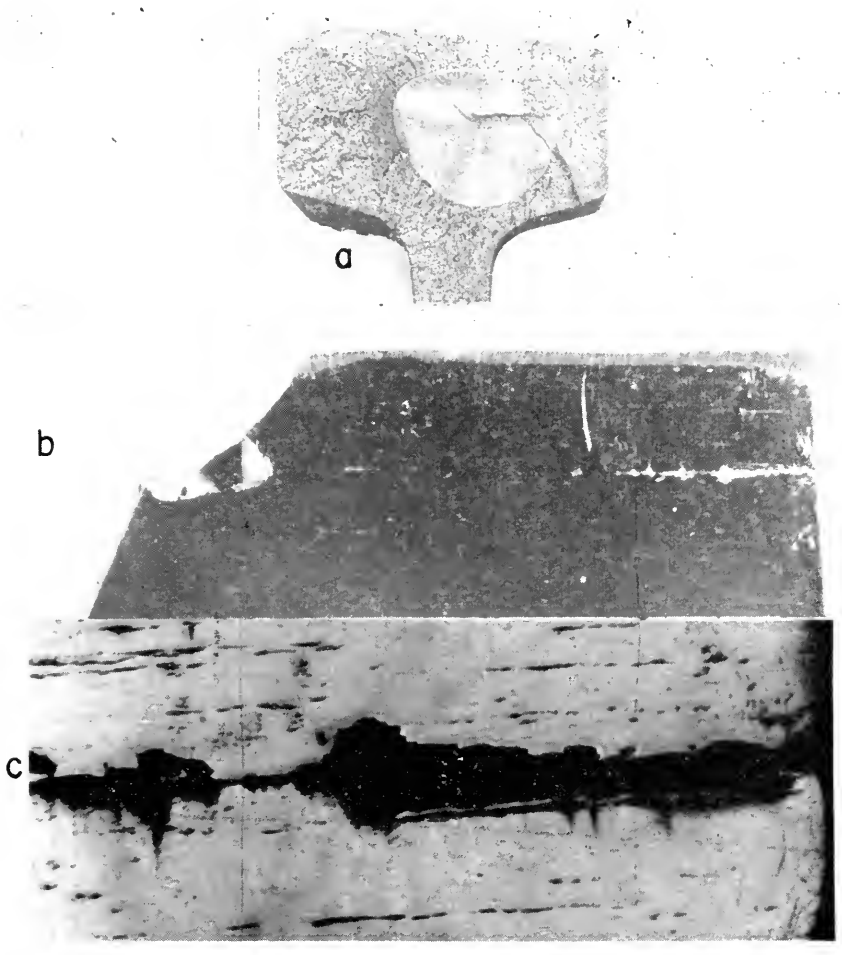

Fig. 2—Transverse fissure from inclusion. Failed rail No. 979.
a. Fissure showing round inclusion as nucleus.
b. Nucleus at left end and other inclusion at right end of micro specimen. Magnification 6×, oblique illumination.
c. Inclusion at right end at 35× magnification.

cropped off the rail end, and the lapped condition in the rail head opened up after about 9 years in service, resulting in a vertical split head failure.

Other Types of Rail Failures

Table 1 lists one failure each from engine burn fracture, base break at rolling seam, bolt hole break, shelling only, fractured base, and two fractures at welded engine burns. All of these are typical of their type except No. 980, classified as fractured base. This fracture was a sudden rupture starting at the top of one edge of the base and progressing about half way across the base. It was found before the rail was laid in

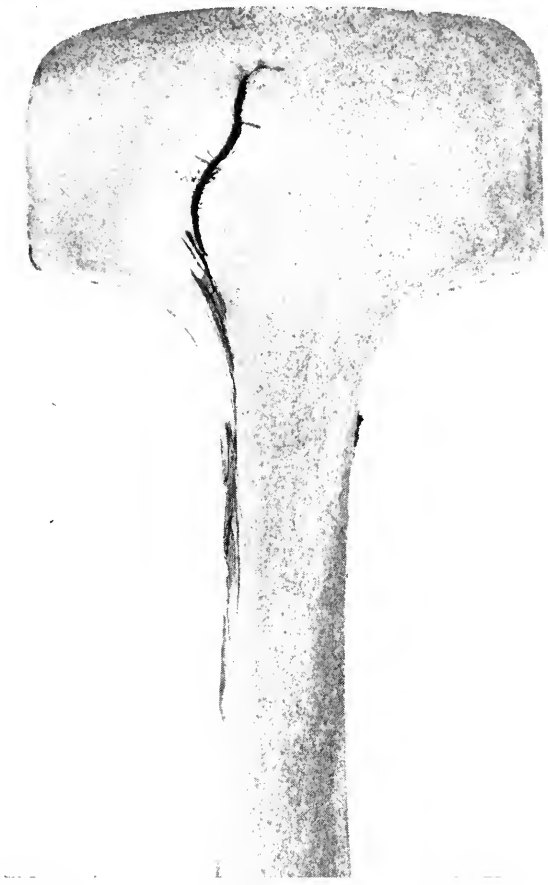

Fig. 3—Vertical split head from rolling defect.
Rail No. 984. Lightly etched with acid.

track and is thought to have been the result of the rail having been dropped, as the fracture was at almost the mid-length of the rail. It was not possible to determine any details of how the base was fractured.

Summary

1. Twenty-five failed control-cooled rails were examined and reported.
2. Only two failures were transverse fissures from shatter cracks and were in Algoma rails rolled before 1951.
3. Six failures were from hot torn steel.
4. One failure, shown in Fig. 2, was a transverse fissure from an inclusion.
5. A vertical split head, shown in Fig. 3, developed from a rolling defect in the bottom rail from an ingot.
6. There were only one or two each of several other common types of rail failures.

Report on Assignment 3

Rail Failures Statistics, Covering (a) all Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail

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These statistics are based on the rail failures reported to December 31, 1957, and are submitted as information. They include the service and detected failures reported by 62 railroads on all of their main-track railway mileage, which constitutes the major part of the main track in the United States and Canada. This report was prepared by Kurt Kannowski, metallurgical engineer of the Association of American Railroads, Engineering Division research staff, under the direction of G. M. Magee, director of engineering research.

The accompanying tables and diagrams indicate the extent of the control of the transverse fissure problem that has been obtained by the use of control-cooled rail and detector car testing, to give data on the quality of each year's rollings for the various mills, and to show the types of failures that are occurring on the various railroads as related to the mill producing the rail.

Transverse Fissure Failures

Fig. 1 shows in line "A" the number of service transverse fissure failures that have occurred and have been reported by all 62 reporting roads from 1919 to 1957, incl. It is gratifying to note that the number of these service transverse fissures have again decreased in 1957 following the slight upturn in 1956 and continuing the trend of decline of these types of failures started in 1943. With the increasing amount of control-cooled rail and the continued use of detector car testing, the level of service transverse fissure failure occurrences has been reduced to a point where further improvements are difficult to effect. However, its importance warrants continued effort towards this goal. The number of detected transverse defects, indicated by line "B", continued during 1957 at about the same level. The following table shows the number of track miles tested by detector cars for the past several years, and it will be noted that there has been no significant change in the amount of detector car testing.

Year Tested	*No. of Roads Reporting*	*Track Miles Tested by Detector Cars*
1953	59	212,280
1954	56	201,134
1955	56	186,322
1956	50	196,882
1957	57	212,082

The data on which lines "A" and "B" of Fig. 1 are based are given in Table 1 and in Table 2 similar data are given for 25 roads which break their transverse detected defects for identification of the type of defect. When this is done it is possible to identify those detected defects that are transverse fissures, and these are shown by line "D". For these same reporting roads the number of service transverse fissure failures are indicated

by line "C". It is apparent from line "D" that the increasing tonnage of control-cooled rail being placed in main line track is having an important effect in the reduction of the development of transverse fissures.

Mill Performance

The number of failures that develop during the first five years of service are considered to be a good criterion of the excellence of mill manufacture and quality. Fig. 2 shows this failure rate from the 1908 rollings to the 1952 rollings, and certainly the decline in this failure rate, which has continued again for this year's reporting, is a tribute to the manufacturers' efforts. Another criterion of mill quality is reflected in Fig. 3 showing the rail failure rate by each year's rollings from 1947 to 1956, incl., separately for the different mills. As stated in the report last year, the relatively high rate of failure for the Algoma 1955 rollings is due to an increase in vertical split head failures and failures within joint bar limits reported by the Canadian Pacific. It is interesting to note that the relatively high failure rates for Colorado, Gary and Lackawanna Mills in 1947 will drop out of the picture in next year's report with the elimination of the 1947 rollings. When this is effected the failure rates for all mills, except Dominion, for the rollings from 1948 to 1957, incl., will indeed be most favorable, barring any unforeseen increase in the rate of failures for the 1957 rollings. Fig. 4, showing the failures per 100 track miles for rolling 1947 to 1956, incl., indicates a very significant reduction between the 1947 rollings and the 1948 rollings when the new RE rail sections were introduced and generally used. To fully appreciate the significance of this decrease, the following comparison is given showing the corresponding failure rates for the old rail sections for the nine year service period up to 1947.

Failures Per 100 Track Miles

Years of Service	*Old Sections*	*New Sections*
1	0.9	0.4
2	2.9	1.5
3	8.6	3.5
4	19.4	9.2
5	34.9	13.2
6	54.8	21.7
7	90.6	35.8
8	119.8	36.7
9	131.5	45.4

It will be noted that there has been approximately a two-thirds reduction in the number of failures for the year with the new rail sections.

Types of Failures

Table 6 shows the number of failures reported in the last 10 years' rollings, classified by type of failure and by mill. Comparison with corresponding data reported last year shows that there has been a substantial reduction in the number of failures of all types, in the CF and DF classification, and in web failures within joint bar limits. It is also interesting to compare the failures of each type for all mills, as shown in Table 6, with the corresponding failure rates for the 1938 to 1947 rollings, incl., and this is given in the following tabulation:

Type of Failure	*Accumulated Failures* *Old Sections*	*New Sections*
TF—verified by University of Illinois	52	40
CF & DF	4600	8468
VSH	1537	780
HSH	1412	640
Other head	1401	2144
Broken	1006	433
Web—in joint	8000	4463
Web—other	3918	757
Base	801	800
All types	24635	18543
Failures per 100 track mile years	9.24	5.79

Comparison of the failure rate for the rollings of these two 10-year periods, one before the new rail sections and the other after the new rail sections were introduced, shows a substantial reduction in vertical split heads, horizontal split heads, broken, and web failures with the new rail sections. On the other hand, the number of CF and DF and other head failures were substantially greater in the new rail sections. However, analysis of the reports shows that the major part of these failures actually occurred in the old sections in the 1947 rollings before the changeover to the new sections. Also the total number of individual types of failures is not adjusted for years of service, and the comparison of failures per 100 track mile years of 5.79 for the new sections and 9.24 for the old sections shows a very significant reduction in the number of failures.

Table 7 is of interest in comparing the failures by type, by mills and by individual railroads. It will be observed that the Canadian Pacific reports a relatively high number of vertical split heads, other head and base failures. Several roads report a relatively high number of CF's and DF's and other head types such as the Norfolk & Western, Southern Pacific, Union Pacific, Chesapeake & Ohio, and Great Northern. On many roads the number of failures reported are surprisingly small.

Table 8, showing the rail failures in the web within the joint bar limits found during 1957, shows that there was some increase in the use of defect detecting equipment during the year. For rail rolled in 1937 and after, the failures reported for 1957 compared with those reported in 1956 show a substantial increase in the number of detected failures with a small decrease in the number of service failures at the bolt hole and a relatively large decrease in the number of service failures at the bolt hole and a relatively large decrease in the number of service failures at other than bolt hole locations.

All failures in control-cooled rail that are thought to be transverse fissures are sent to the University of Illinois for verification by Professor Cramer as a part of the cooperative rail failure investigation sponsored jointly by the AAR and the AISI. Table 9 shows the results to date of the examination of the submitted failures. Of these transverse fissure failures, 81 percent were from hot torn steel, 4 percent from inclusions and 15 percent from shatter cracks due to improper control-cooling procedure. Ten additional transverse fissures were reported this year and only two of these were transverse fissures from shatter cracks, both occurring on the Canadian Pacific in Algoma rollings from 1949 and 1950, respectively.

TABLE 1 - SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS BY RAILROADS AND BY YEAR FAILED - ALL ROLLINGS BY ALL PROCESSES

	Service Failures											Detected Failures										
Year Failed	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total
AT&SF	92	103	39	52	54	18	19	16	15	7	415	1358	1449	1110	1169	1088	970	908	1278	1120	1178	11628
ACL	14	7	12	9	4	7	4	1	3	2	63	1491	919	944	758	741	853	851	836	594	648	8635
B&O	177	100	156	100	91	100	76	59	150	150	1159	713	780	733	745	641	596	696	650	752	909	7215
B&OCT	9	5	1	2	0	2	4	5	12	6	46	2	15	5	2	2	0	3	2	1	2	34
Ban Aroos	0	0	1	0	0	0	1	0	0	0	2	26	16	19	7	11	24	22	16	33	23	197
B&LE	5	3	3	2	2	5	0	1	1	1	23	0	0	0	0	138	36	0	26	27	45	272
B&A	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	52	41	93
B&M	31	16	14	7	24	21	25	25	15	19	197	379	300	375	356	311	292	284	300	282	250	3129
CP	181	131	77	75	47	47	31	39	26	20	674	3546	3787	2866	3800	4251	1504	1805	1375	1258	976	25168
C. of Ga.	31	18	17	24	14	12	10	4	5	0	135	426	275	274	243	301	0	367	570	426	694	3576
C&O (Sys.)	64	37	22	29	43	21	16	39	19	52	342	1119	850	514	643	684	683	562	383	523	200	6161
C&El	33	41	17	15	21	18	19	14	14	1	193	817	320	265	212	97	150	206	152	136	253	2108
C&NW	149	118	84	85	74	72	62	73	38	38	793	976	1159	816	1216	817	836	861	778	807	675	8941
CB&Q	144	65	59	59	28	23	17	12	8	7	422	954	975	465	679	687	463	940	922	795	825	7705
CI&L	7	0	4	4	5	2	5	0	0	0	27	114	77	151	80	58	58	75	81	124	66	884
CMStP&P	89	61	48	42	45	44	30	21	21	11	412	914	1080	675	763	733	982	928	810	893	864	8642
CRI&P	83	47	48	56	46	49	27	22	21	13	412	596	620	445	369	537	322	412	528	744	1076	5649
C&S	3	5	2	0	4	-	2	0	1	0	17	189	72	164	55	182	-	308	133	140	124	1367
D&H	12	12	6	10	10	5	0	0	0	0	55	314	508	306	430	367	327	314	97	219	121	3003
DL&W	17	8	7	3	5	-	-	-	-	-	40	319	186	270	225	257	-	-	-	-	-	1257
D&RGW	31	15	16	14	-	-	6	3	4	0	89	695	373	741	645	-	-	455	514	502	436	4361
Erie	58	43	24	19	20	19	9	10	15	3	220	776	570	543	475	459	435	469	270	317	275	4589
FEC	55	39	27	1	7	0	0	4	0	0	133	182	243	26	13	30	94	175	129	73	87	1052
GTW	27	19	11	9	7	16	6	4	9	1	109	110	123	118	85	71	96	74	82	67	99	925
GN	175	+102	85	94	63	47	45	42	29	24	706	1531	936	1167	1069	1525	932	1163	914	1362	1262	11861
GM&O	35	-	-	-	-	-	-	-	-	-	35	274	-	-	-	-	-	-	-	-	-	274
IC (Sys.)	59	69	53	55	28	33	25	10	15	5	352	1650	1284	1296	1226	1279	1088	908	830	826	782	11169
JCL	65	37	48	14	14	11	9	7	7	5	217	0	0	0	0	56	15	56	83	75	71	356
KCS	10	8	4	6	6	0	8	1	2	10	55	94	73	100	93	94	89	58	47	54	37	739
L&HR	0	0	0	1	1	0	0	0	0	0	2	0	0	0	11	8	8	6	6	1	3	43
L&NE	5	0	0	0	1	0	2	0	0	2	10	36	4	12	12	12	0	14	15	0	15	120
LV	14	6	14	12	20	8	2	8	2	8	94	55	126	87	163	105	108	123	94	147	72	1080

TABLE 1 (Continued)

	Service Failures											Detected Failures										
Year Failed	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total
LI	-	0	0	0	0	0	0	12	-	9	21	-	25	26	18	25	15	14	49	-	13	185
L&N	115	60	48	63	40	40	29	29	27	30	481	933	864	743	843	926	711	592	696	589	606	7503
Me. Cent.	0	7	6	2	3	2	-	1	8	5	34	0	74	130	89	55	46	-	36	36	43	509
MStP&SSM	21	17	11	11	6	0	0	10	1	1	78	95	73	104	116	138	81	632	48	68	67	1422
MKT	30	24	16	19	13	14	8	8	18	3	153	576	532	359	290	162	270	259	212	245	187	3092
MP Lines	4	24	*57	72	51	42	23	11	6	11	301	553	518	1479	1308	1267	981	783	725	594	574	8782
NC&StL	9	9	7	6	5	4	1	1	2	0	44	104	59	45	43	43	11	3	6	10	7	331
NYC (Sys.)#	173	165	154	177	130	155	114	59	95	63	1285	1484	1508	1306	1344	1284	1151	1612	508	956	1152	12305
NYC&StL	37	21	19	16	13	10	9	7	6	4	142	128	118	106	84	77	60	54	39	41	32	739
NYC Trans.	15	-	-	-	-	-	-	-	-	-	15	0	-	-	-	-	-	-	-	-	-	-
NYNH&H	4	2	3	1	0	2	4	5	4	2	27	172	79	116	77	48	73	56	62	81	118	882
NYO&W	24	12	21	25	10	8	6	1	3	-	110	0	0	11	20	86	110	182	28	37	-	474
N&W	2	3	3	1	3	2	4	3	7	3	31	129	84	130	124	157	113	135	103	166	403	1544
NP	129	90	73	11	1	0	0	1	9	4	318	431	473	347	377	372	417	429	339	436	381	4002
PRR##	255	430	92	103	85	122	76	67	129	95	1454	1865	1166	1876	1844	1322	1792	1574	1600	1880	1783	16702
P&LE	1	0	0	1	0	0	0	0	0	0	2	36	22	29	12	20	26	22	26	10	9	212
Reading	0	0	0	0	0	0	0	0	0	0	0	1236	404	241	451	205	396	460	271	290	274	4228
RF&P	10	6	1	0	0	1	0	1	0	0	19	514	195	172	128	64	55	25	24	18	18	1213
Rutland	0	0	0	4	0	2	2	0	3	4	15	0	0	0	28	0	0	0	0	0	0	28
StL - SF	74	52	17	16	0	3	5	6	7	3	183	664	639	515	377	410	398	346	309	568	1674	5900
SAL	11	18	22	7	14	7	12	9	6	10	116	412	299	454	324	318	344	344	300	253	259	3307
SP	162	98	68	75	76	69	63	55	38	23	727	1243	1012	952	960	970	1005	728	794	934	833	9431
Southern	171	98	98	106	70	63	41	32	20	24	723	2643	2009	1927	1682	1490	1622	2157	1732	1442	1263	17967
T&NO	112	99	90	88	79	55	28	16	1	0	568	951	1006	958	788	749	606	708	456	463	353	7038
T&P	46	22	16	8	7	5	6	3	2	5	120	393	173	152	114	90	70	115	58	57	49	1271
UP	55	19	23	13	15	13	18	10	7	1	174	4149	3613	3429	4142	4157	4632	5003	4074	4044	3113	40356
Virginian	6	1	0	0	1	0	0	0	3	7	18	152	24	60	73	45	39	41	57	66	84	641
W. Md.	25	3	16	15	14	8	4	0	2	0	87	418	302	138	133	156	153	59	105	84	35	1583
W&LE	0	3	7	-	-	-	-	-	-	-	10	8	5	11	-	-	-	-	-	-	-	24
ALL ROADS	3166	2398	1767	1639	1320	1207	913	767	837	693	14707	38445	32396	30303	31333	30178	26138	29376	24578	25718	25439	293904

*Includes all transverse defects
-No report received
#Includes IHB failures
##Including LI RR and PRSL 1940 to 1948 inclusive
+Includes engine burn fractures

TABLE 2 - SERVICE AND VERIFIED DETECTED TRANSVERSE FISSURE FAILURES BY RAILROAD AND BY YEAR FAILED REPORTED BY ROADS WHICH BREAK THEIR DETECTED RAILS. ALL ROLLINGS BY ALL PROCESSES

	Service Failures											Detected Failures										
Year Failed	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	Total
AT&SF	92	103	39	52	54	18	19	16	15	7	415	298	488	359	362	308	213	0	199	193	303	2723
B&O	-	-	-	-	-	-	-	-	150	150	300	-	-	-	-	-	-	-	-	2	4	6
Ban & Aroos	0	0	1	0	0	0	1	0	0	0	2	26	11	19	7	11	24	22	16	33	23	192
B&LE	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	1	1	2
CP	181	131	77	75	47	47	31	39	26	20	674	3545	3787	2866	1900	2125	0	1	0	0	1	14225
C. of Ga.	31	18	17	24	14	12	10	4	5	0	135	-	-	-	-	-	-	66	250	209	442	967
C&EI	33	41	17	15	21	18	19	/	/	/	164	312	320	245	187	97	0	0	/	/	/	1161
CB&Q	144	65	59	59	28	23	17	12	8	7	422	887	884	426	528	544	372	420	365	326	363	5115
CMStP&P	89	61	48	42	45	44	30	21	21	11	412	734	901	557	567	495	546	571	550	602	596	6119
C&NW	149	118	84	85	74	72	62	73	38	38	793	-	-	-	-	-	-	6	10	5	0	21
CRI&P	83	47	48	56	46	49	27	22	21	13	412	-	-	-	-	-	-	1	272	406	606	1285
C&S	3	5	2	0	4	-	2	0	1	0	17	56	37	53	45	71	-	131	63	44	47	547
Erie	58	43	24	19	20	19	9	10	15	3	220	595	469	463	350	276	326	336	192	233	200	3440
GTW	27	19	11	9	7	16	6	4	9	1	109	106	123	118	85	71	96	74	81	67	99	920
GN	175	102	85	94	63	47	45	42	29	24	706	631	599	519	546	662	362	433	303	354	448	4857
L&NE	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	12	12
Ll*	-	0	0	0	0	0	0	12	-	9	21	-	25	26	18	25	15	0	6	-	13	128
L&N	115	60	48	63	40	40	29	29	27	30	481	662	554	483	524	300	545	0	0	0	0	3068
Me. Cent.	-	-	-	-	-	-	-	-	8	5	13	-	-	-	-	-	-	-	-	12	20	32
MStP&SStM	21	17	11	11	6	0	0	/	/	/	66	-	-	-	-	-	-	10	/	/	/	10
MKT	30	24	16	19	13	14	8	8	18	3	153	280	264	176	265	157	266	214	212	243	186	2263
MP Lines	4	24	10	28	8	8	23	11	6	11	133	-	-	-	-	-	-	557	544	445	430	1976
NC&StL	9	9	7	6	5	4	1	1	2	0	44	87	58	39	34	38	10	0	4	6	5	281
NYC (Sys.)	173	165	154	177	130	155	114	59	95	63	1285	690	693	673	648	722	759	1220	410	610	728	7153
NYC&StL	37	21	19	16	13	10	9	7	6	4	142	128	116	0	0	77	60	54	38	39	30	542
NYNH&H	4	2	3	1	0	2	4	5	4	2	27	132	60	107	64	43	57	45	48	71	109	736
NYO&W	24	12	21	25	10	8	6	1	3	-	110	-	-	-	-	-	-	68	28	37	-	133
N&W	2	3	3	1	3	2	4	3	7	3	31	29	28	32	16	36	19	40	18	48	61	327
NP	129	90	73	11	1	0	0	1	9	4	318	355	441	41	22	68	58	87	90	129	140	1431
PRR	255	430	92	103	85	122	76	67	/	/	1230	404	16	-	-	-	-	-	0	/	/	420
P&LE	1	0	0	1	0	0	0	0	0	0	2	0	0	3	3	7	9	0	0	0	0	22
RF&P	10	6	1	0	0	1	0	/	/	/	18	147	49	22	12	0	1	13	/	/	/	244
Rutland	0	0	0	4	0	2	2	0	3	4	15	0	0	0	14	0	0	0	0	0	0	14
Virginian	6	1	0	0	1	0	0	0	3	7	18	1	0	0	0	0	3	0	0	0	0	4
W. Md.	25	3	16	15	14	8	4	/	/	0	85	210	141	66	77	81	25	59	/	/	35	694
Total	1910	1620	986	1011	752	741	558	447	530	422	8977	10315	10064	7293	6274	6214	3766	4428	3699	4115	4902	61070

*Included in PRR prior to 1949.
-No report received.
/Have discontinued breaking detected failures.

TABLE 3 - TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1947 - 1956 INCL., REPORTED BY 58 RAILROADS.

Year Rolled	OH CONTROL COOLED ONLY	
	TONS	TRACK MILES
1947	1,533,329	7,236.28
1948	1,407,756	6,601.31
1949	1,254,278	5,966.41
1950	1,311,038	6,335.78
1951	1,229,261	5,908.58
1952	987,006	4,796.63
1953	1,207,782	5,683.69
1954	823,831	3,833.60
1955	883,125	4,085.60
1956	865,017	4,024.40
TOTAL	11,502,423	54,472.28

TABLE 4 - SERVICE AND DETECTED FAILURES OF ALL TYPES EXCEPT ENGINE BURN FAILURES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1957 PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS, FROM ALL MILLS.

Year Rolled	YEARS OF SERVICE									
	1	2	3	4	5	6	7	8	9	10
1947	0.9	3.1	6.5	13.6	25.5	39.6	62.5	83.4	106.0	127.6
1948	0.7	1.6	3.6	7.5	11.5	19.1	26.4	35.6	45.4	
1949	1.7	4.1	7.2	10.0	15.8	21.7	28.8	36.7		
1950	3.1	6.0	9.6	14.1	19.6	25.9	35.8			
1951	2.0	3.4	5.0	10.4	16.3	21.7				
1952	2.0	2.8	4.3	7.9	13.2					
1953	0.8	2.0	4.0	9.2						
1954	0.5	1.3	3.5							
1955	0.7	1.5								
1956	0.4									

A

TABLE 5 - TRACK MILES AND 1957 FAILURES, ALL TYPES, IN ROLLINGS 1947 TO 1956, INCL.
OPEN-HEARTH CONTROL-COOLED RAIL ONLY

ROAD	TRACK MILES BY MILL										1957 FAILURES	
	ALG	CARN	COLO	DOM	GARY	INLD	LACKA	STLTN	TENN	TOTAL	EBFs EXCL.	EBFs ONLY
AT&SF			2146		1115	268				3529	60	2
ACL		9						547	1090	1646	20	
B&O		681			367	5	105	689		1847	49	26
B&OCT						37				37	2	1
Ban Aroos		3						121		124	11	
B&LE		67								67		
Bos & Alb							101			101		
B&M		36					20	59		115	6	
CP	3780			768			73			4621	755	
C. of Ga.									301	301		
C&O (Sys.)	21	68			898	620	235	106		1948	30	4
C&EI					125	19				144	9	
C&NW					606	143	174			923	3	
CB&Q			1088		878	173				2139	8	
CI&L					101	44				145		
CMStP&P					1197	358				1555	7	
CRI&P			96		842	256				1194	6	2
CCC&StL -P&E					471	67	5			543	12	1
C&S			379							379	1	8
D&H								206		206	2	1
D&RGW			422							422	25	
Erie		449			301	25	95	6		876	1	9
FEC		28						81	259	368	3	5
GTW					195	56	73			324	6	
GN			540		767	291	248			1846	91	
IC					1233	538			325	2096	11	
JCL								157		157		
KCS					256	34			12	302		
L&HR								31		31		
L&NE								36		36		
LV							301			301		
LI										0		
L&N					48				1278	1326	27	2
Me. Cent.							92	3		95	2	
MStP&SSM					295	218	67			580	13	
MKT			63		152	34				249		
MP Lines			1179		664	172			219	2234	3	
NC&StL					4				420	424		
NYC-E					34		867			901	262	4
NYC-W					464	33				497	43	
NYC&StL		100			417	79	206			802	180	
NYNH&H		86						248		334	26	4
N&W		801						252		1053	313	23
NP			496		382	105	175			1158	25	2
PRR		733			227	62		970		1992	31	6
P&LE		142								142	3	2
Reading								475		475		
RF&P								180		180		
Rutland										0		
St. L-SF						22			820	842		
SAL		3						730	661	1394	4	1
SP			2906							2906	526	49
Southern					16	15		581	1311	1923	25	1
T&NO			654						124	778	19	
T&P			289						158	447		
UP			2218		889	128				3235	1389	5
Va.		92						147		239	14	1
W. Md.		150						236		386	10	
TOTAL	3801	3448	12476	768	12944	3802	2837	5861	6978	52915	4033	159

NOTE: The following railroad did not report in 1958 and was omitted from this table: DL&W

TABLE 6 - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1947 TO 1956, INCLUSIVE FROM DATE ROLLED TO DECEMBER 31, 1957, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

OH CONTROL COOLED RAIL ONLY

MILL	ACCUMULATED FAILURES TO DEC. 31, 1957 (EXCL. EBFs)									ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
	TF VER U of I	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB		BASE				
							IN JT.	OTHER					
ALGOMA	12	18	336	8	279	83	683	34	646	2099	3800	22519	9.32
CARNEGIE (ET)	1	632	15	34	63	26	383	30	10	1194	3757	23600	5.06
COLORADO	0	5555	136	420	941	61	1060	495	17	8685	12926	73858	11.76
DOMINION	0	0	63	2	53	7	469	8	35	637	766	4234	15.04
GARY	8	1241	78	67	502	103	753	79	25	2856	13140	78360	3.64
INLAND	1	317	34	19	43	27	69	28	7	545	3898	22118	2.46
LACKAWANNA	6	123	56	13	126	44	676	10	48	1102	2985	18925	5.82
STEELTON	12	438	37	27	58	28	141	24	4	769	6199	37058	2.07
TENNESSEE	0	144	34	50	79	54	229	49	17	656	7205	39628	1.65
ALL MILLS	40	8468	789	640	2144	433	4463	757	809	18543	54676	320300	5.79
FAILURES PER 100 TRACK MILE YEARS	.01	2.64	.25	.20	.67	.14	1.39	.24	.25	5.79			

Definition of symbols;

TF - Transverse Fissure
CF - Compound Fissure
DF - Detail Fracture
VSH - Vertical Split Head
HSH - Horizontal Split Head
EBF - Engine Burn Fracture

TABLE 7 - ACCUMULATED FAILURES OF ALL TYPES FOR OH CONTROL COOLED RAIL, ONLY IN ROLLING 1947 - 1956, INCL., ACCUMULATED TO DECEMBER 31, 1957 SERVICE AND DETECTED, SEGREGATED BY ROADS AND MILLS.

ROADS	TF Ver U of I	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1957	EBFs Only Accum. Total	EBFs Only 1957
ALGOMA													
CP	12	18	336	8	279	83	683	34	646	2099	491	0	0
TOTAL	12	18	336	8	279	83	683	34	646	2099	491	0	0
CARNEGIE													
B&O	0	15	6	3	5	2	37	10	2	80	15	14	1
B&LE	0	0	0	2	0	0	0	0	0	2	0	0	0
B&M	1	3	0	0	9	3	0	0	0	16	1	0	0
C&O (Sys.)	0	12	0	0	0	0	17	0	0	29	5	4	0
Erie	0	1	0	2	0	1	3	0	0	7	1	7	4
NYC&StL	0	5	0	5	9	13	140	2	0	174	19	0	0
NYNH&H	0	4	1	4	0	1	39	0	0	49	19	0	0
N&W	0	570	4	9	33	2	37	12	7	674	229	34	15
PRR	0	15	1	4	7	1	14	0	1	43	16	107	1
P&LE	0	3	2	3	0	0	89	2	0	99	3	18	2
Va.	0	4	0	1	0	2	1	4	0	12	3	0	0
W. Md.	0	0	1	1	0	1	6	0	0	9	9	0	0
TOTAL	1	632	15	34	63	26	383	30	10	1194	320	184	23
COLORADO													
AT&SF	0	88	16	10	14	0	49	0	0	177	54	0	0
CB&Q	0	3	0	1	2	0	1	0	0	7	3	1	0
C&S	0	0	0	0	1	0	0	0	0	1	1	14	8
D&RGW	0	57	1	1	0	0	3	0	0	62	25	0	0
GN	0	3	4	1	6	0	3	0	0	17	7	0	0
MP Lines	0	3	6	5	3	2	8	2	0	29	2	14	0
NP	0	0	1	0	45	6	7	4	0	63	12	4	2
SP	0	382	71	266	249	49	919	380	15	2331	526	237	49
T&NO	0	1	4	15	4	3	1	18	0	46	17	1	0
UP	0	5018	33	121	617	1	69	91	2	5952	1069	32	3
TOTAL	0	5555	136	420	941	61	1060	495	17	8685	1716	303	62

TABLE 7 - CONTINUED

ROADS	TF Ver U of I	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1957	EBFs Only Accum. Total	EBFs Only 1957
DOMINION													
CP	0	0	63	2	53	7	469	8	35	637	248	0	0
TOTAL	0	0	63	2	53	7	469	8	35	637	248	0	0
GARY													
AT&SF	0	0	1	2	2	0	9	0	0	14	6	2	2
B&O	0	2	7	0	2	1	7	2	0	21	2	33	4
C&O (Sys.)	0	100	9	4	7	4	22	3	0	149	15	15	3
C&EI	0	2	1	0	9	0	28	0	0	40	9	0	0
C&NW	0	1	0	1	12	4	42	3	3	66	2	0	0
CB&Q	0	0	1	3	3	0	3	0	0	10	3	0	0
CMStP&P	0	8	5	0	0	6	3	0	1	23	7	0	0
CRI&P	0	0	4	0	2	14	3	1	3	27	5	2	2
CCC&StL	0	13	3	0	20	1	26	8	1	72	12	14	1
Erie	0	0	0	0	0	0	0	0	0	0	0	5	5
GTW	1	0	13	1	3	8	7	0	1	34	3	0	0
GN	0	157	1	3	154	17	30	1	1	364	58	0	0
IC	0	8	3	1	6	2	14	4	0	38	7	3	0
KCS	0	0	3	1	0	0	0	0	0	4	0	0	0
L&N	0	0	0	0	0	0	1	0	0	1	0	0	0
MStP&SStM	0	0	4	0	1	11	1	0	7	24	7	0	0
MKT	0	0	0	0	1	0	0	0	0	1	0	0	0
MP Lines	0	1	4	2	2	1	198	2	1	211	0	1	0
NYC - E	0	0	0	0	1	0	0	0	0	1	0	0	0
NYC - W	7	9	4	3	8	17	148	11	1	208	43	29	0
NYC&StL	0	2	2	2	5	4	109	3	2	129	85	0	0
NP	0	0	4	2	11	13	16	5	0	51	10	4	0
PRR	0	2	1	0	0	0	4	0	0	7	2	4	4
UP	0	936	8	42	253	0	82	36	4	1361	278	22	2
TOTAL	8	1241	78	67	502	103	753	79	25	2856	554	134	23

TABLE 7 - CONTINUED

ROADS	TF Ver U of I	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1957	EBFs Only Accum. Total	EBFs Only 1957
INLAND													
AT&SF	0	0	0	0	0	0	2	0	0	2	0	0	0
B&O	0	0	0	0	0	0	1	1	0	2	0	0	0
B&OCT	0	0	0	0	0	0	0	2	0	2	2	1	1
C&O (Sys.)	1	44	6	4	3	9	11	9	2	89	6	13	0
C&EI	0	0	2	0	4	0	0	0	1	7	0	0	0
C&NW	0	0	3	3	1	0	7	0	1	15	0	0	0
CB&Q	0	2	0	0	1	0	0	0	0	3	2	0	0
CMStP&P	0	0	4	1	0	2	2	0	0	9	0	0	0
CRI&P	0	0	0	1	1	3	0	0	0	5	1	0	0
GTW	0	0	0	0	0	2	7	0	0	9	1	0	0
GN	0	24	4	1	19	0	6	0	2	56	19	0	0
IC	0	1	3	0	4	0	6	2	1	17	3	0	0
MStP&SStM	0	1	5	0	0	4	8	2	0	20	4	0	0
MKT	0	0	0	0	1	0	0	0	0	1	0	0	0
MP Lines	0	2	3	0	0	0	2	0	0	7	1	0	0
NYC&StL	0	2	2	1	2	5	0	1	0	13	3	0	0
NP	0	0	0	0	1	1	1	0	0	3	0	0	0
PRR	0	0	0	0	0	0	1	0	0	1	0	0	0
StL - SF	0	0	0	1	0	0	0	0	0	1	0	0	0
UP	0	241	2	7	6	1	15	11	0	283	42	0	0
TOTAL	1	317	34	19	43	27	69	28	7	545	84	14	1
LACKAWANNA													
B&O	0	2	5	0	3	1	20	4	0	35	11	12	2
Bos & Alb	0	0	1	0	0	0	0	0	0	1	0	0	0
B&M	1	12	0	0	3	0	0	0	0	16	5	0	0
CP	0	0	2	2	18	0	28	0	13	63	16	0	0
C&O (Sys.)	1	37	0	2	2	0	18	2	0	62	4	2	1
C&NW	0	0	0	2	4	4	1	0	9	20	1	0	0
GTW	0	0	32	1	5	6	2	0	4	50	2	0	0
GN	0	17	2	1	48	0	4	0	2	74	7	0	0
LV	0	1	0	0	0	0	0	0	7	8	0	0	0
Me. Cent.	0	0	0	0	0	0	2	0	0	2	2	0	0
MStP&SStM	0	0	0	0	0	17	0	1	8	26	2	0	0
NYC - E	1	49	14	4	36	2	487	2	4	599	262	8	4
NYC&StL	3	5	0	1	6	10	107	1	0	133	73	0	0
NP	0	0	0	0	1	4	7	0	1	13	3	0	0
TOTAL	6	123	56	13	126	44	676	10	48	1102	388	22	7

TABLE 7 - CONTINUED

ROADS	TF Ver U of I	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1957	EBFs Only Accum. Total	EBFs Only 1957
STEELTON													
ACL	0	0	0	1	0	0	69	0	1	71	0	1	0
B&O	8	57	10	6	11	2	20	4	0	118	21	49	19
Ban Aroos	0	0	3	1	7	1	0	0	0	12	11	0	0
B&M	0	1	0	0	5	1	1	1	0	9	0	5	0
C&O (Sys.)	1	100	3	2	7	0	1	3	0	117	0	2	0
D&H	0	14	1	4	1	0	0	1	0	21	2	1	1
FEC	0	1	0	1	0	0	0	1	0	3	1	1	0
JCL	0	1	2	0	0	0	1	2	0	5	0	0	0
NYNH&H	0	2	4	2	1	0	17	0	0	26	7	15	4
N&W	2	187	2	5	12	1	17	3	2	231	84	16	8
PRR	0	49	3	3	10	2	11	0	0	78	13	107	1
Reading	0	2	0	0	0	2	2	0	0	6	0	0	0
RF&P	1	1	0	0	3	0	0	0	0	5	0	0	0
SAL	0	0	6	1	0	2	0	0	0	9	2	1	1
Southern	0	0	2	0	1	2	0	0	0	5	3	0	0
Va.	0	24	0	1	0	15	2	9	1	52	11	1	1
W. Md.	0	0	1	0	0	0	0	0	0	1	1	0	0
TOTAL	12	438	37	27	58	28	141	24	4	769	156	199	35
TENNESSEE													
ACL	0	0	1	1	3	3	128	7	3	146	20	4	0
C. of Ga.	0	0	5	2	1	4	7	1	1	21	0	7	0
FEC	0	5	0	3	0	1	1	1	0	11	2	23	5
IC	0	2	2	2	6	0	2	0	0	14	1	0	0
L&N	0	130	14	25	8	3	34	26	2	242	27	10	2
MP Lines	0	0	0	1	0	0	3	0	0	4	0	1	0
NC&StL	0	3	2	6	19	2	6	1	2	41	0	0	0
StL - SF	0	1	4	6	3	4	5	1	0	24	0	0	0
SAL	0	1	2	2	1	1	0	0	0	7	2	0	0
Southern	0	2	4	1	37	36	42	2	3	127	22	26	1
T&NO	0	0	0	1	1	0	1	10	6	19	2	0	0
TOTAL	0	144	34	50	79	54	229	49	17	656	76	71	8
ALL MILLS	40	8468	789	640	2144	433	4463	757	809	18543	4033	927	159

TABLE 8
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1957
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and After				Joints Inspected with Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
AT&SF	41	75	24	0	184	255	102	0	1,887,857
ACL	4	61	96	100	6	963	13	17	99,597
B&O	4	0	1442	96	0	0	53	12	0
B&OCT	0	0	28	4	0	0	1	1	14,200
Ban & Aroos	10	2	3	4	11	1	4	1	20,700
B&LE	0	0	0	0	0	0	0	1	-
Bos & Alb	0	0	0	0	0	0	1	0	0
B&M	47	15	27	3	0	8	0	1	401,260
CP	177	169	63	22	413	489	225	134	893,988
C. of Ga.	0	0	0	0	0	0	2	0	0
C&O (Sys.)	19	8	28	19	1	4	6	3	12,040
C&EI	0	0	19	0	0	0	21	0	0
C&NW	123	160	245	233	6	14	76	81	19,731
CB&Q	8	0	87	2	45	11	96	23	38,159
CI&L	44	4	42	13	0	0	3	1	-
CMStP&P	603	89	271	44	4	1	14	8	381,000
CRI&P	13	1	61	69	3	0	24	51	-
CCC&StL	1	43	25	55	0	6	28	42	79,196
C&S	0	0	3	0	0	0	0	0	-
D&H	0	0	11	2	0	0	0	1	-
D&RGW	15	95	6	21	20	285	9	23	-
Erie	12	21	15	9	3	21	9	6	31,589
GTW	2	1	64	2	9	0	15	3	18,658
GN	72	0	31	0	45	0	52	0	348,088
IC	5	1	18	7	4	1	38	13	-
JCL	112	6	10	0	3	1	1	0	10,640
KCS	0	0	1	1	0	0	0	1	-
L&HR	0	0	4	0	0	0	1	0	0
L&NE	4	1	9	1	0	0	0	0	-
LV	192	155	24	0	0	0	0	0	84,186

TABLE 8 (Cont.)
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1957
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and After				Joints Inspected with Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
LI	0	0	0	9	0	0	0	0	-
L&N	48	67	73	0	25	44	76	0	260,000
Me. Cent.	32	32	5	0	1	0	1	0	-
MStP&SStM	41	0	48	0	0	0	17	0	289,600
MKT	0	0	3	0	0	0	23	0	0
MP Lines	0	0	6	8	0	0	13	25	0
NYC - E	195	31	43	28	572	555	75	43	156,120
NYC - W	9	9	127	11	39	24	47	7	-
NYC&StL	0	5	35	4	530	1	285	6	-
NYNH&H	3	2	409	36	0	0	91	26	0
N&W	2	75	9	1	15	210	7	1	15,295
NP	5	45	482	7	0	0	284	124	-
PRR	995	361	1786	378	574	474	252	112	1,230,637
P&LE	0	0	0	0	13	10	5	2	13,229
Reading	2	0	0	0	2	0	0	0	-
RF&P	0	0	0	0	0	0	0	250	2,120
StL - SF	23	133	19	19	115	610	10	50	-
SAL	5	3	9	1	0	1	12	0	-
Southern	7	93	0	0	0	345	0	0	61,748
SP	0	15	6	0	5	328	12	51*	119,450
T&NO	73	91	0	0	342	78	0	0	158,307
T&P	120	13	8	4	180	35	8	0	159,271
UP	76	80	2	0	270	90	14	5	2,015,000
Va.	17	0	0	0	1	1	0	0	-
W. Md.	0	0	0	0	3	0	2	1	-
Totals	3161	1962	5727	1213	3444	4866	2028	1166	8,821,666

*Includes all service head and web separation failures, records do not indicate whether or not these failures occurred within joint bar limits.

TABLE 9 - ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, BY ROAD, MILL AND YEAR ROLLED TO OCTOBER 1, 1958

Roads	Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	Total
CN	Algoma												1 (a)							1
CP	Algoma					1 (b)	1 (a)	2 (b)		1 (a)	1 (a)		2 (b)	1(a)1(b)	1 (b)	6 (b)	5 (b)			22
Mich. C	Algoma					1 (b)			1 (b)											2
PM	Algoma						1 (a)													1
NYNH&H	Carnegie (ET)			1 (c)																1
N&W	Carnegie (ET)					1 (a)				1 (c)								1 (c)		3
AT&SF	Colorado					1 (c)														1
CB&Q	Colorado							1 (c)												1
CN	Dominion						1 (b)													1
AT&SF	Gary			1 (b)																1
C&NW	Gary		3 (b)	2 (b)																5
CB&Q	Gary		3 (b)																	3
GN	Gary		1 (b)																	1
NYC	Gary				1 (b)															1
Wabash	Gary			1 (b)																1
AT&SF	Inland							2 (a)												2
CB&Q	Inland									1 (a)	3 (a)									4
C&O	Inland	1 (a)		3 (a)				6 (a)			1 (a)	1 (a)			1 (a)			1 (a)	2 (a)	16
CMStP&P	Inland										2 (a)									2
CRI&P	Inland												1 (a)							1
MKT	Inland										1 (b)		1 (a)							2
UP	Inland					3 (a)	3 (a)													6
B&M	Lackawanna										1 (a)									1
C&O	Lackawaona															1 (a)	1 (a)			2
LV	Lackawaona								3 (a)	1 (a)										4
NYC	Lackawanna								1 (a)	1 (a)	2 (a)									4
NYC&StL	Lackawanna								2 (a)		3 (a)			3 (a)	1 (a)					9
AT&SF	Steelton			3 (a)																3
B&O	Steelton						1 (a)	1 (a)	3 (a)	1 (a)	1 (a)	1 (a)	1 (a)		1 (a)		3 (a)	3 (a)	4 (a)	20
B&M	Steelton						2 (a)		1 (a)											3
C of NJ	Steelton							1 (a)		1 (a)										2
C&O	Steelton	5 (a)		1 (a)	4 (a)		3 (a)			1 (a)			1 (a)			1 (a)				15
D&H	Steelton				1 (a)	2 (a)	1 (c)		1 (a)	1 (a)										6
MP	Steelton			1 (a)																1
N&W	Steelton					1 (a)	4 (a)		8 (a)					2 (a)			1 (a)			16
NYNH&H	Steelton			3 (a)		2 (a)	1 (a)		1 (a)	2 (a)										9
PRR	Steelton		2 (a)																	2
RF&P	Steelton			1 (a)			1 (a)								2 (a)					4
SAL	Steelton							2 (a)		1 (a)										3
So. Ry.	Steelton							1 (a)		2 (a)										3
SP	Steelton		18 (a)	3 (a)	6 (a)	5 (a)	1 (a)													33
T&NO	Steelton		2 (a)	1 (a)																3
Va.	Steelton						2 (a)	1 (a)	1 (a)											4
C. of Ga.	Tennessee									1 (c)										1
IC	Tennessee									1 (c)										1
L&N	Tennessee							1 (c)												1
SP	Tennessee		1 (b)																	1
TOTAL		6	30	21	12	17	22	18	22	15	15	2	7	7	6	8	10	5	6	229

TABLE 9 (Cont.) - SUMMARY BY MILLS

Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	Total
Algoma					2	2	2	1	1	1		3	2	1	6	5	1		27
Carnegie (ET)			1		1				1										3
Colorado	*				1		1												2
Dominion						1													1
Gary		7	4	1															12
Inland	1		3		3	3	8		1	7	1	2		1			1	2	33
Lackawanna								6	2	6			3	1	1	1			20
Steelton	5	22	13	11	10	16	6	15	8	1	1	2	2	3	1	4	3	4	127
Tennessee		1					1		2										4
TOTAL	6	30	21	12	17	22	18	22	15	15	2	7	7	6	8	10	5	6	229

Note: (a) TRANSVERSE FISSURE from hot torn steel, (b) TRANSVERSE FISSURE from shatter cracks due to improper cooling. (c) TRANSVERSE FISSURE from inclusion. Summary - 35 T. F.'s from shatter cracks, 9 T. F.'s from inclusions, 185 T. F.'s from hot torn steel.

*No cc rail rolled.

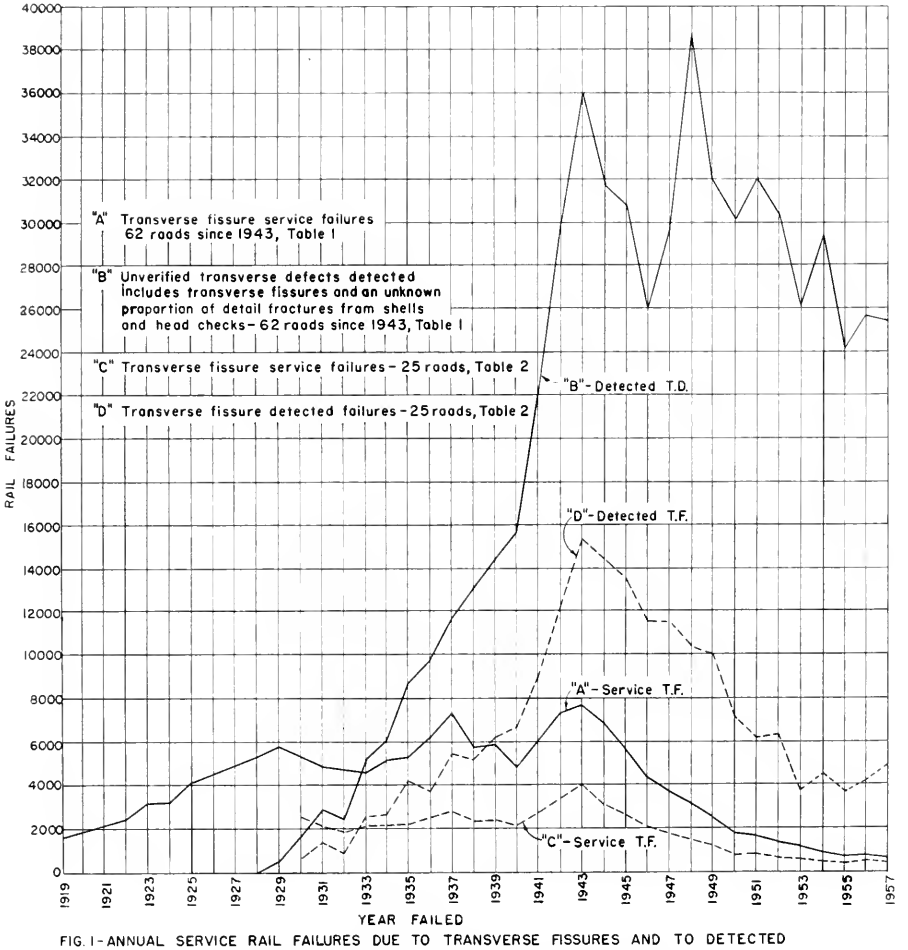


FIG. 1 - ANNUAL SERVICE RAIL FAILURES DUE TO TRANSVERSE FISSURES AND TO DETECTED TRANSVERSE DEFECTS AS REPORTED BY ALL RAILROADS.

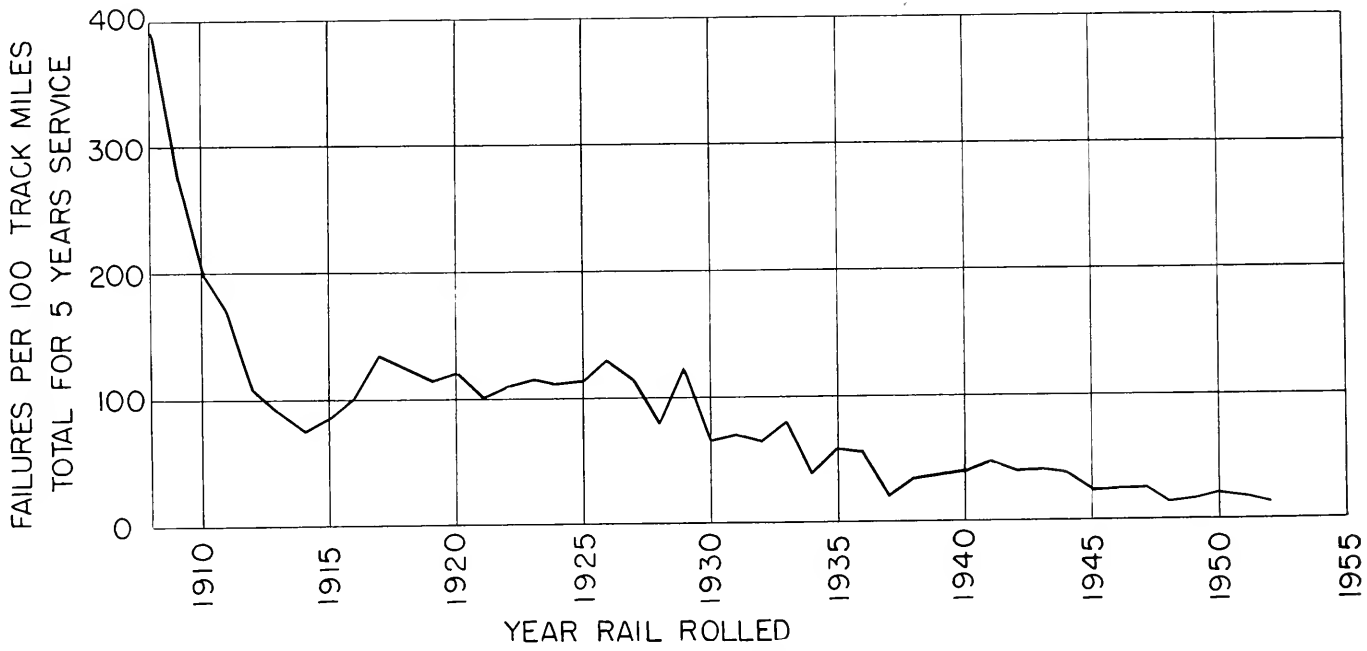


FIG. 2- SERVICE AND DETECTED FAILURES IN UNITED STATES AND CANADA

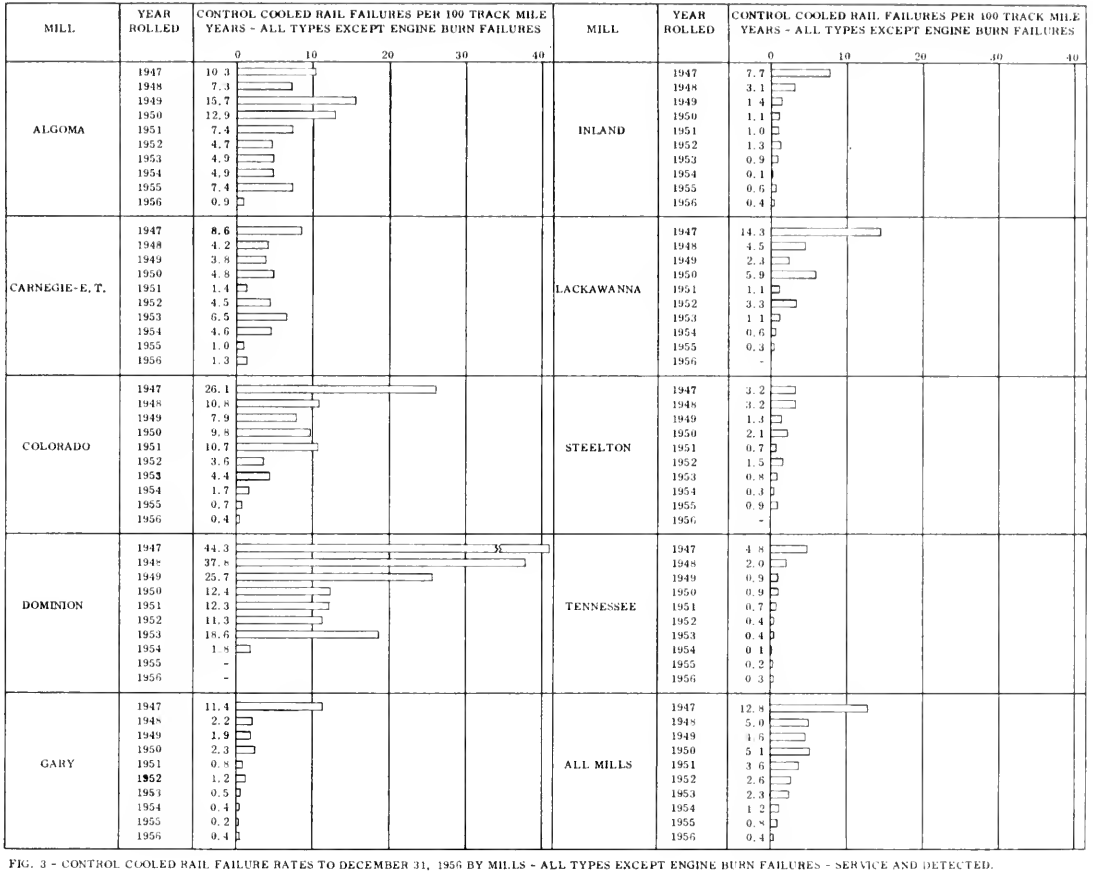


FIG. 3 - CONTROL COOLED RAIL FAILURE RATES TO DECEMBER 31, 1956 BY MILLS - ALL TYPES EXCEPT ENGINE BURN FAILURES - SERVICE AND DETECTED.

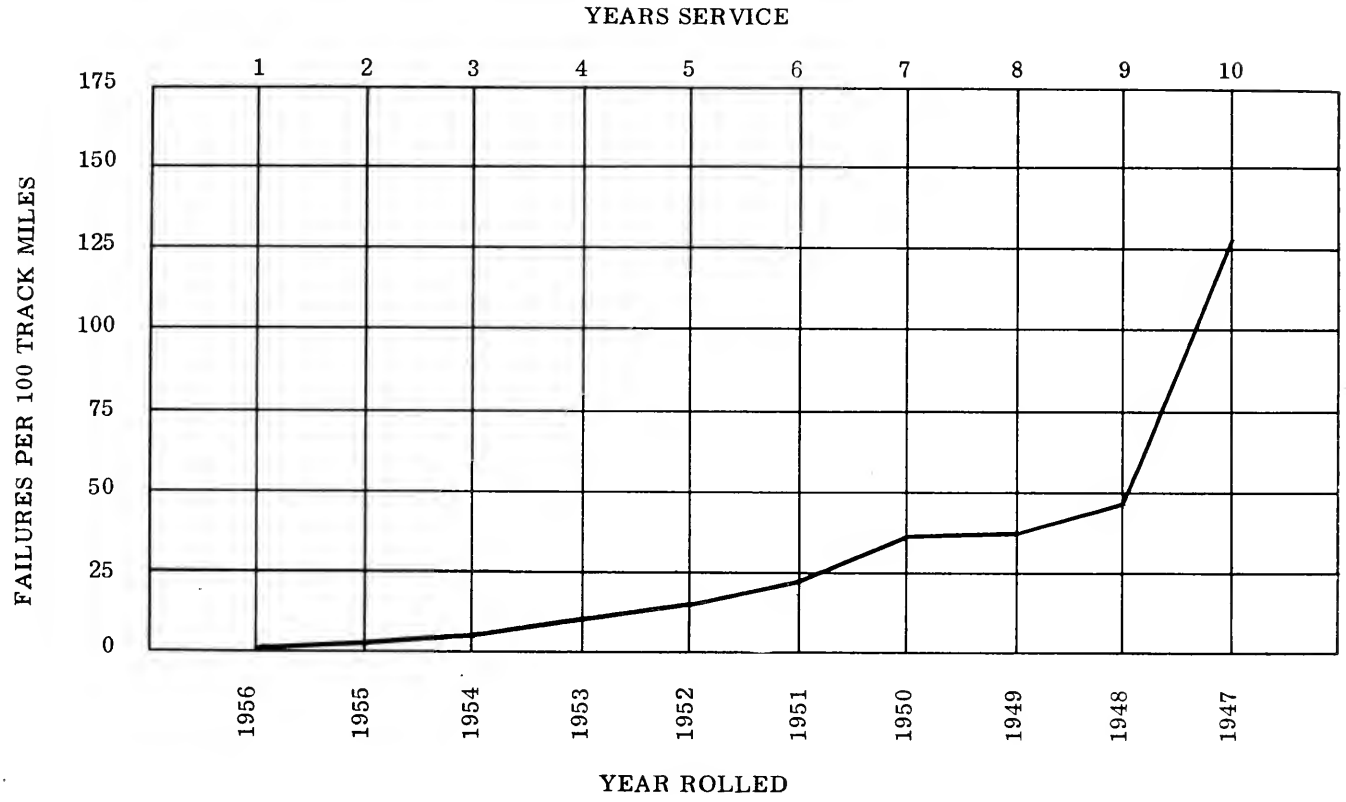


Fig. 4 - Control Cooled Rail Failures to December 31, 1957 Per 100 Track Miles - All Types Excluding Engine Burn Fractures - Service and Detected.

Report on Assignment 4

Rail End Batter: Causes and Remedies

K. K. Kessler (chairman, subcommittee), E. L. Anderson, Blair Blowers, B. Bristow, R. M. Brown, T. F. Burris, R. E. Catlett, C. J. Code, L. S. Crane, W. J. Cruse, J. K. Gloster, J. C. Jacobs, C. C. Lathey, R. F. Lawson, H. S. Loeffler, Lee Mayfield, C. E. Morgan, G. L. P. Plow, R. B. Rhode, J. G. Roney, H. F. Smith, A. P. Talbot, R. P. Winton, J. E. Yewell.

This is a report, presented as information, on the progress made during 1958 on this assignment, which is outlined in the Proceedings, Vol. 56, 1955, page 929. Four rolling-load machines have been in operation on this project during the latter part of the year, with the result that the outlined program on the rolling-load tests has been completed. The metallurgical examinations of these tests are now in progress.

Since the results of the metallurgical examinations correlate closely with the results and failures of the rolling-load tests, a report on the rolling-load tests, which now might be misleading, will be postponed until all of the work is completed.

Report on Assignment 5

Economic Value of Various Sizes of Rail

J. C. Jacobs (chairman, subcommittee), E. L. Anderson, S. H. Barlow, Blair Blowers, T. F. Burris, C. A. Colpitts, C. O. Conatser, L. S. Crane, W. J. Cruse, G. H. Echols, C. E. R. Haight, W. H. Hobbs, N. W. Kopp, W. B. Leaf, H. S. Loeffler, Embert Osland, R. B. Rhode, J. G. Roney, J. F. Shaffer, W. D. Simpson, H. F. Smith, A. P. Talbot, J. S. Wearn, W. L. Young.

Your committee submits the following report of progress as information. It is a continuation of Study A, reflecting changes in the test mileage and computed to show averages after 14 years. The labor and material averages are computed to compensate for the decrease in test track mileage.

Study A

Result of Study of Illinois Central Railroad Northward Track, Mattoon to Savoy, Ill. Test Sections of 112-Lb and 131-Lb Rail

112-Lb Rail

MP 152.24–172.00 laid in 1942 and 1943
Original test included:
19.76 track miles
18 turnouts
1 railroad crossing
22 public road crossings
2 private grade crossings
24″ joint bars
Changes in rail mileage:
1950—MP 152.09–152.24 laid in 115-lb, 0.15 miles added to test.
1952—MP 155.87–160.52 relaid in 132-lb, 4.65 miles dropped from test.
1953—MP 160.52–163.55 relaid in 132-lb, 3.03 miles dropped from test.
1954—MP 152.09–155.87 relaid in 132-lb, 3.78 miles dropped from test.
1956—MP 170.79–172.00 relaid in 132-lb, 1.21 miles dropped from test.
Average annual traffic density—28,000,000 gross tons

131-Lb Rail

MP 132.00–152.24 laid in 1944
Original test included:
20.24 track miles
21 turnouts
3 railroad crossings
22 public road crossings
6 private grade crossings
36″ joint bars
Changes in rail mileage:
1950—MP 152.09–152.24 laid in 115-lb, 0.15 miles dropped from test.

COMPARISON OF THE TWO SECTIONS—COST OF INVESTMENT—1944 PRICES

Item	Investment Charges per Mile 112 Lb	131 Lb
Gross cost—rail and other track material	$12,643	$14,413
Less estimated salvage Cr.	4,284	Cr. 5,011
Net cost—rail and other track material	$ 8,359	$ 9,402
Labor cost to lay	1,338	1,473
Total cost	$ 9,697	$10,875
Estimated life—based on 1957 condition	14 years	20 years
Anual cost—rail and other track material	$ 597	$ 470
Labor to lay	96	74
Interest at 6 percent*	839	953
Total annual investment cost	$ 1,532	$ 1,497

* On gross outlay for material and labor.

MAINTENANCE LABOR AND MATERIAL PER MILE

112 Lb					131 Lb				
Year	Miles Maintained	Man-Hours	Cross Ties	Cu Yd Ballast	Year	Miles Maintained	Man-Hours	Cross Ties	Cu Yd Ballast
1943	19.76	2,480	716	628	1944	20.24	2,606	1,065	647
1944	19.76	413	5	17	1945	20.24	131		30
1945	19.76	701	236	251	1946	20.24	370	5	114
1946	19.76	1,166	416	579	1947	20.24	748	172	301
1947	19.76	645	208	273	1948	20.24	245	38	185
1948	19.76	1,005	186	294	1949	20.24	670	10	116
1949	19.76	1,574	541	423	1950	20.09	1,642	402	323
1950	19.91	694	174	159	1951	20.09	614	59	52
1951	19.91	667	48	193	1952	20.09	1,144	62	304
1952	15.26	748	30	140	1953	20.09	1,089	139	120
1953	12.23	1,110	91	292	1954	20.09	392		21
1954	8.45	543	44	83	1955	20.09	631	91	64
1955	8.45	239	32	159	1956	20.09	535	10	52
1956	7.24	401	8	0	1957	20.09	394		
Total 14 Years		12,386	2,735	3,491			11,211	2,053	2,329

AVERAGE OF 14 YEARS

	112-Lb		131-Lb		Savings by Use of 131-Lb	
	Charge	Percent	Charge	Percent	Charge	Percent
Man-hours	885		801		84	
Cost at $1.19*	$1,053	55	$ 953	61	$ 100	30
Cross ties	195		147		48	
Cost at $3.07*	$ 599	32	$ 451	29	$ 148	45
Ballast (stone and slag) cu yd	249		166		83	
Cost at $1.00*	$ 249	13	$ 166	10	$ 83	25
Total Maintenance	$1,901		$1,570		$ 331	
Percent		100		100		100
Investment charges	$1,532		$1,497		$ 35	
Total Cost	$3,433		$3,067		$ 366	
Percent						11.0

*Average prices 1943–1956.

Summary

The original test involved 19.76 miles of 112-lb and 20.24 miles of 131-lb rail. The study covers maintenance costs beginning in 1943 for the 112-lb rail and 1944 for the 131-lb. Eight and one-half miles of 112-lb rail were laid in 1942 and had one year of service prior to the beginning of the test records. The last of the 112-lb section was removed in 1957 after a maximum of 15 years of service, although the greater part was removed after 14 years or less.

At the beginning of this study the estimate of service in the first location was 15 years for the 112-lb and 25 years for the 131-lb. Records have shown a life of 15 years for the 112-lb to be reasonable; however the anticipated service of the 131-lb has been reduced to 20 years. Final reports of maintenance costs for the 112-lb rail will be included in this report next year, but the study will be continued with respect to 131-lb rail during the remainder of its life in its present location.

As pointed out in previous reports, the greatest savings realized through the use of the heavier rail have been in cross ties, possibly due to the use of long and heavier joint bars, larger tie plates and greater rail rigidity. Cross ties in both sections are renewed in accordance with similar maintenance standards and conditions.

Report on Assignment 6

Service Tests of Various Types of Joint Bars

T. A. Blair (chairman, subcommittee), R. E. Catlett, Jr., C. J. Code, L. S. Crane, W. J. Cruse, V. E. Hall, J. C. Jacobs, K. K. Kessler, N. W. Kopp, W. B. Leaf, H. S. Loeffler, Embert Osland, G. L. P. Plow, E. F. Salisbury, J. K. Shaffer, S. H. Shepley, J. S. Wearn, R. P. Winton.

This is a progress report, offered as information, covering two service tests of joint bars for 115 RE and 132 RE rail, established in 1948 and 1949.

The investigation is being conducted by the Engineering Division research staff of the Association of American Railroads under the general supervision of G. M. Magee, director of engineering research. H. E. Durham, research engineer track, is in direct charge of the assignment.

Description of Service Test Installation

These two service tests have been described in previous reports of the committee. Details, including drawings of the cross sections, and physical properties of the joint bars are given in Vol. 52, page 636. The rail in both tests was end hardened in the field. Most of the test sections were installed in 1948, but some of the bars were not available at that time and the remaining sections were added in 1949. The service tests were established for the purpose of studying variations in joint bar design and the effects of the new AREA bolt hole spacing, the old AREA bolt hole spacing and a four-hole spacing of joint bars, 36 in long.

The service test sections of joint bars for 132 RE rail are in the eastbound main track of the Atchison, Topeka & Santa Fe Railway near Streator, Ill., 100 miles west of Chicago. Each section is ½ mile in length, all located on tangent track. The test installation includes the following test sections:

Location V—132 RE headfree, 36-in 6–6–7⅛–6–6-in new AREA punching, 6-hole bars, placed August 1948.

Location W—132 RE headfree, 36-in 9–9⅛–9-in punching, 4-hole bars, placed August 1948.

Location X—132 RE headfree, 36-in 6½–6½–5⅛–6½–6½-in, old AREA punching, 6-hole bars, placed August 1948.

Location Y—132 Rail Joint Company, K–42, headfree, 36-in, 6½–6½–5⅛–6½–6½-in, old AREA punching, 6-hole bars, placed March 1949.

Location Z—132 Rail Joint Company, K–44, headfree, long-toe design, 39-in, 6½–6½–5⅛–5½–6½ in, old AREA punching, 6-hole bars, placed March 1949.

As indicated in the above, this test installation includes a comparison of three designs of joint bars for 132 RE rail, and for the AREA headfree joint bar includes three different bolt hole spacings. Fig. 1, page 572, AREA Proceedings, Vol. 51, 1950, shows the location of each test section related to mile posts and highways.

Rail surface profiles and measurements of out-to-out distances and camber were taken in July 1958. From the date of installation until that time, sections V, W, and X have carried 177 million gross tons of traffic, section Y, 167 million gross tons and section Z, 158 million gross tons.

The service tests of the 115 RE joint bars are in the westbound main track of the Chicago & North Western Railway near Sterling, Ill., 106 miles west of Chicago on the Omaha line. Each test section includes 100 joints and is approximately 2000 ft long. This test installation includes the following sections, all on tangent track.

Location AA—115 RE headfree, 36-in, 9–9⅛–9-in punching, 4-hole bars, placed November 1948.

Location BB—115 RE headfree, 36-in, 6–6–7⅛–6–6–-in new AREA punching, 6-hole bars, placed November 1948.

Location CC—115 Rail Joint Company, K–22, headfree, 36-in, 6–6–7⅛–6–6-in, new AREA punching, 6-hole bars, placed November 1948.

Location DD—115 Rail Joint Company, K–4, headfree, 36-in, 6–6–7⅛–6–6-in, new AREA punching, 6-hole bars, placed November 1948.

Location EE—115 Rail Joint Company, K–24, headfree, long-toe design, 39-in, 6–6–7⅛–6–6-in new AREA punching, 6-hole bars, placed May 1949.

It will be observed that the above includes four different designs of joint bars, all of which have the new AREA punching and, in addition, section AA with the new 115 RE headfree design has a 4-hole punching for a 36-in length bar. Fig. 2 on page 573 of AREA Proceedings, Vol. 51, 1950, shows the location of each test section related to mile posts and highways. Figs. 1 and 2, this report, show views of typical test sections.

Measurements of this service test installation were taken in April 1958. The initial or base readings for all sections of the C&NW test were taken in May 1949, and from that time until the date of the April 1958 measurements the track had carriel 130 million gross tons of traffic.

Discussion of Test Data

Santa Fe Test

Graphs of top of rail camber, rail surface profile and pull-in of the joint bars for 132 RE rail are given in Figs. 3, 4 and 5, respectively. The top of rail camber data (Fig. 3) indicate very little change in the droop of the joints since the measurements were taken in 1956. The changes observed were too small to be significant.

Whereas much of the rail end batter developed before field end hardening following the laying of the new rail, the rail surface profiles indicate a trend toward the maximum batter in sections V and W. The average batter of the leaving and receiving rails in those two sections was 80 percent greater than the average of sections X, Y and Z. This appears, in part at least, to be caused by the greater rail gaps in sections V and W. The difference in the level between the leaving and receiving rails at the ¼-in points is approximately 100 percent greater in section W than in the other four sections which are about equal. It appears that this difference may be due to the use of 4-hole joint bars, as a similar condition exists in section AA containing 4-hole, 36-in bars on the C&NW.

The change in out-to-out distance at the bottom of the middle of the joint bars, reflecting the amount of fishing surface wear, has progressed in a fairly consistent manner. The change in out-to-out was the greatest in section W with the 4-hole bars followed by the 6-hole bars in section V. Likewise, the average batter and difference in level at the ¼-in points were the largest in section W, with section V next in magnitude. The least change is in section Z with the Rail Joint Company long-toe bars which has carried 11 percent less traffic than sections V, W and X and 5 percent less traffic than section Y. There is still ample takeup remaining in all bars.

Since June 1956 four 132 K–44 long-toe bars in section Z have developed transverse cracks in the slots for the line spikes. These cracks have not progressed sufficiently to warrant changing out the bars.

No out-of-face surfacing has been done on the test sections since the inspection of June 1956.

Chicago & North Western Test

Graphs of top of rail camber, rail surface profile and pull-in for the joint bars for 115 RE rail are given in Figs. 6, 7 and 8. The change in top of rail camber since June 1956 is very slight, with the greatest change occurring in the north rail of section AA. This difference is consistent with the rail surface profile, but does not appear significant.

The rail surface profiles show an increase in height of the north rail of section AA and the south rail of section BB. This apparently reflects the original camber in the bars rather than some other condition. Other rails have remained approximately the same since 1956 or have lowered slightly. The profiles of sections DD and EE are lower than the others, in which respect they are similar to comparable bars in sections Y and Z of the test of the AT&SF. The maximum batter occurred in sections BB and CC, but the differences between these sections and the other three were small. On the C&NW as in the Santa Fe tests, the 4-hole RE joints (section AA), had the largest difference in level between the leaving and receiving rails at the ¼-in points. This difference was 60 percent lager than that of the other four test sections.

The change in out-to-out distance, shown in Fig. 8, appears to have lessened during the last test period which is, no doubt, due to the elimination of six high-speed passenger trains per day during the last half of 1955. Section AA with the 36-in, 4-hole RE bars continues to have less change than the other sections, which is contrary to the trend of the 4-hole bars in section W on the AT&SF. The greater tonnage to date and greater speed of both freight and passenger trains on the Santa Fe are no doubt a factor.

The 1958 inspection found all test bars to be in good condition with no visible change having taken place during the last test period.

No out-of-face surfacing has been done since the beginning of the test.

Conclusions

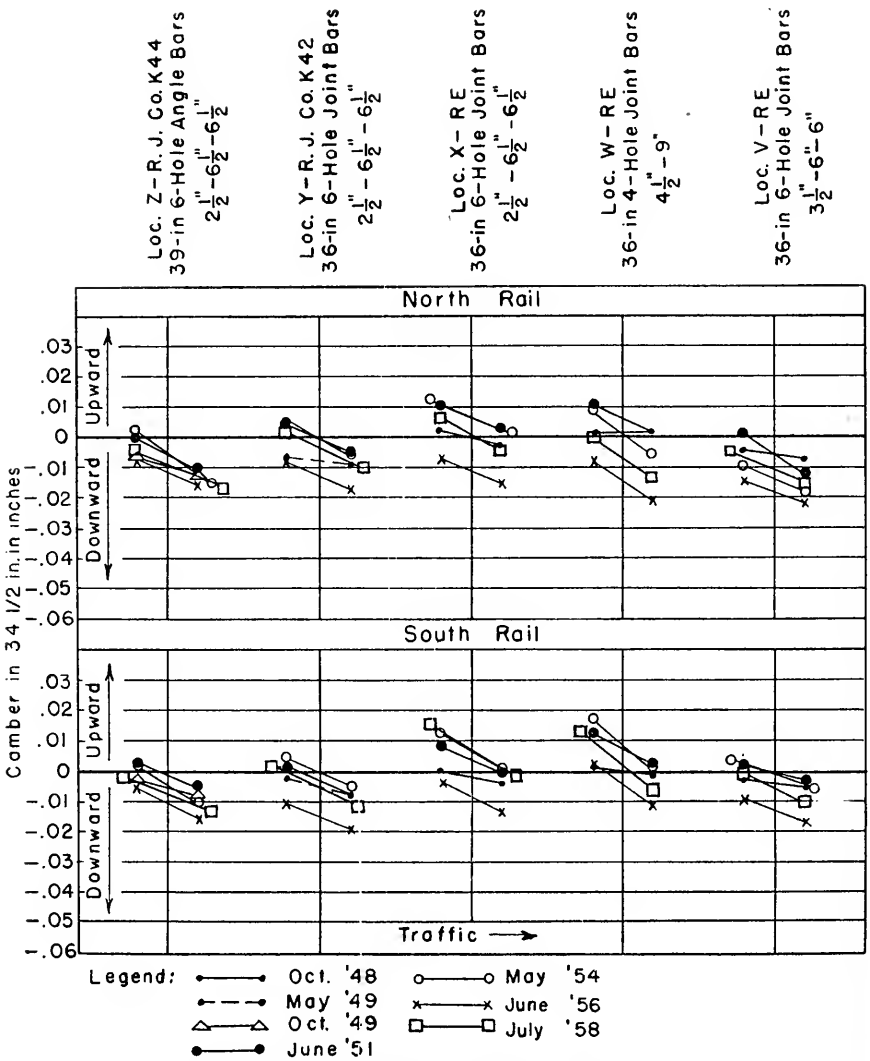
After ten years of service the test sections are showing good performance with little difference except that the 4-hole bars are showing slightly more difference in the level at the ¼-in points of the rail ends. The long-toe bars on the Santa Fe continue to show a slight tendency toward developing cracks in the spike slots, although the progression is slow.

Acknowledgement

The Association is grateful to the Santa Fe and C&NW for their assistance and cooperation in the conduct of the tests.

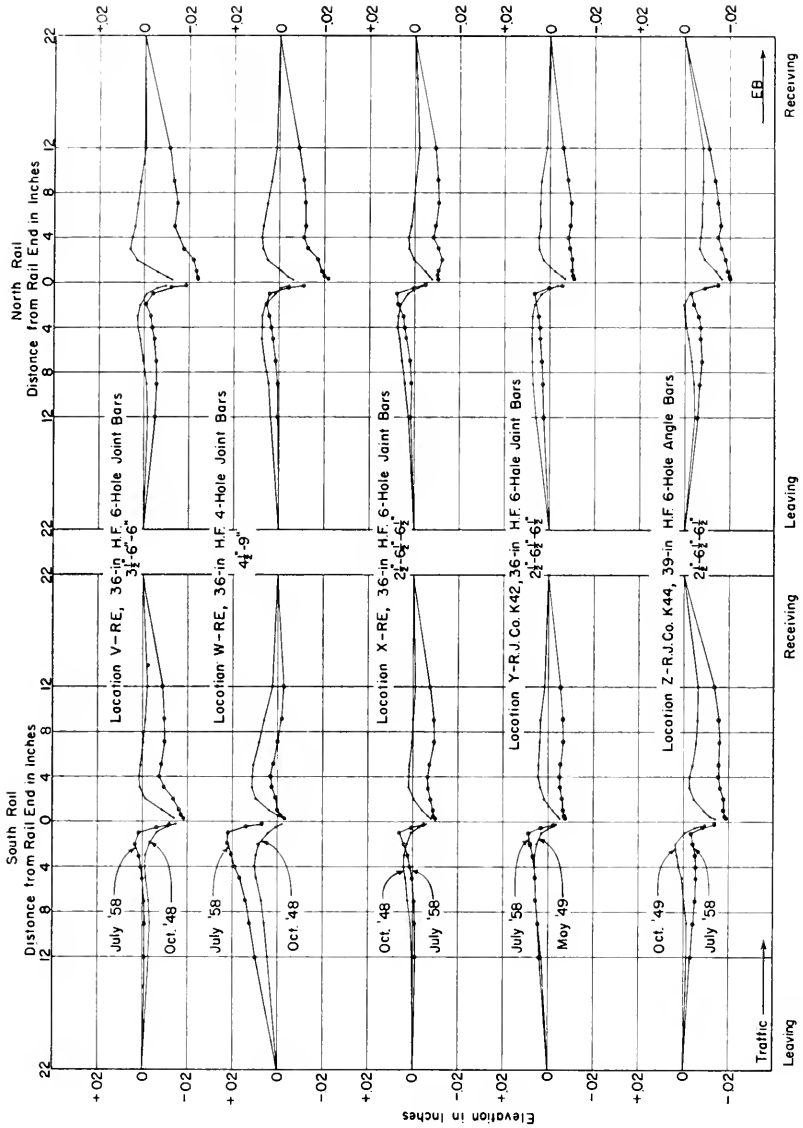
Fig. 1—General view of section W on the Santa Fe looking east along the eastbound track near M. P. 98.

Fig. 2—AAR employee measuring out-to-out distance in section AA on the North Western. View looking east along westbound track near M. P. 108.



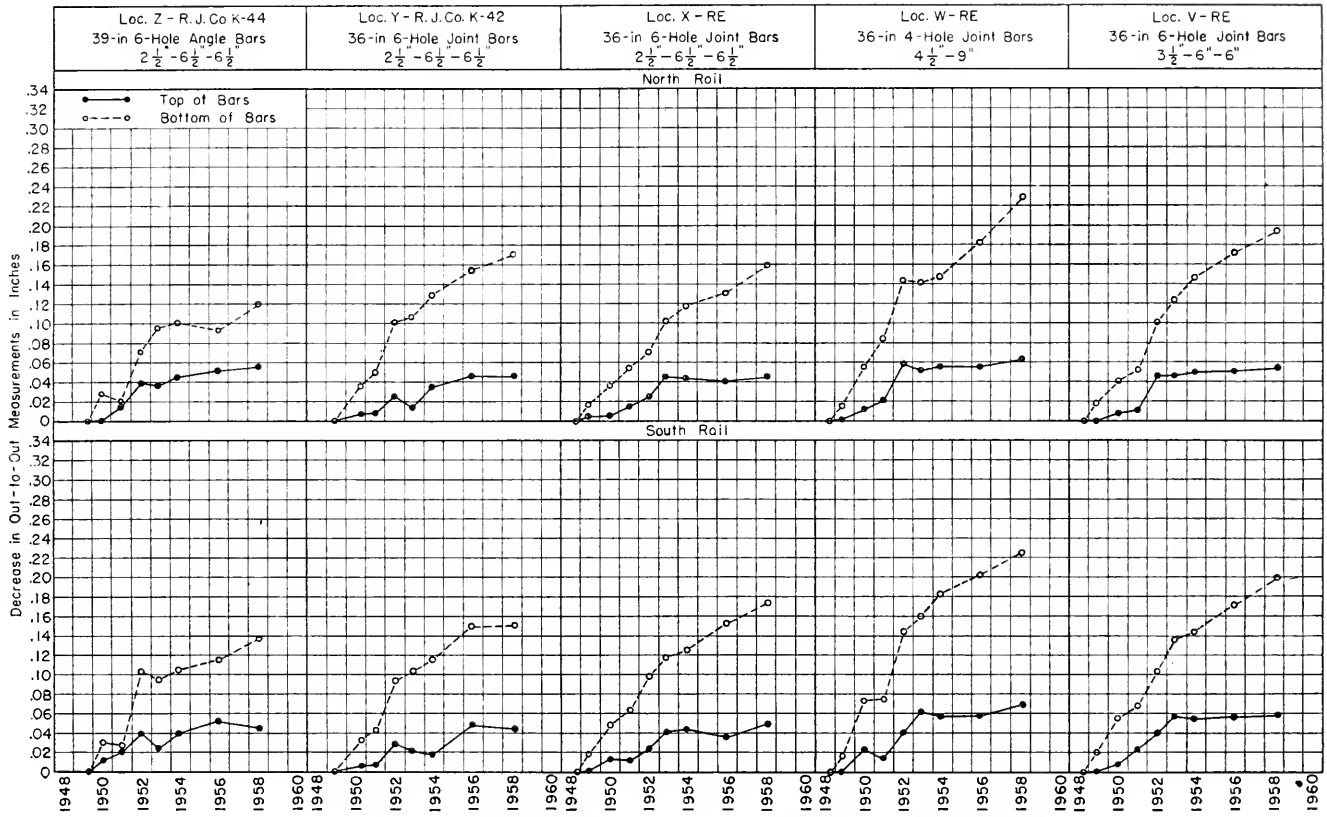
Note: Camber readings are the average of 30 joints each of North and South rail at all test locations, taken 1/2 in. from rail ends.

Fig. 3.— Top of Rail Camber in 34 1/2 In., A.T. & S.F. Ry. 1948 to 1958



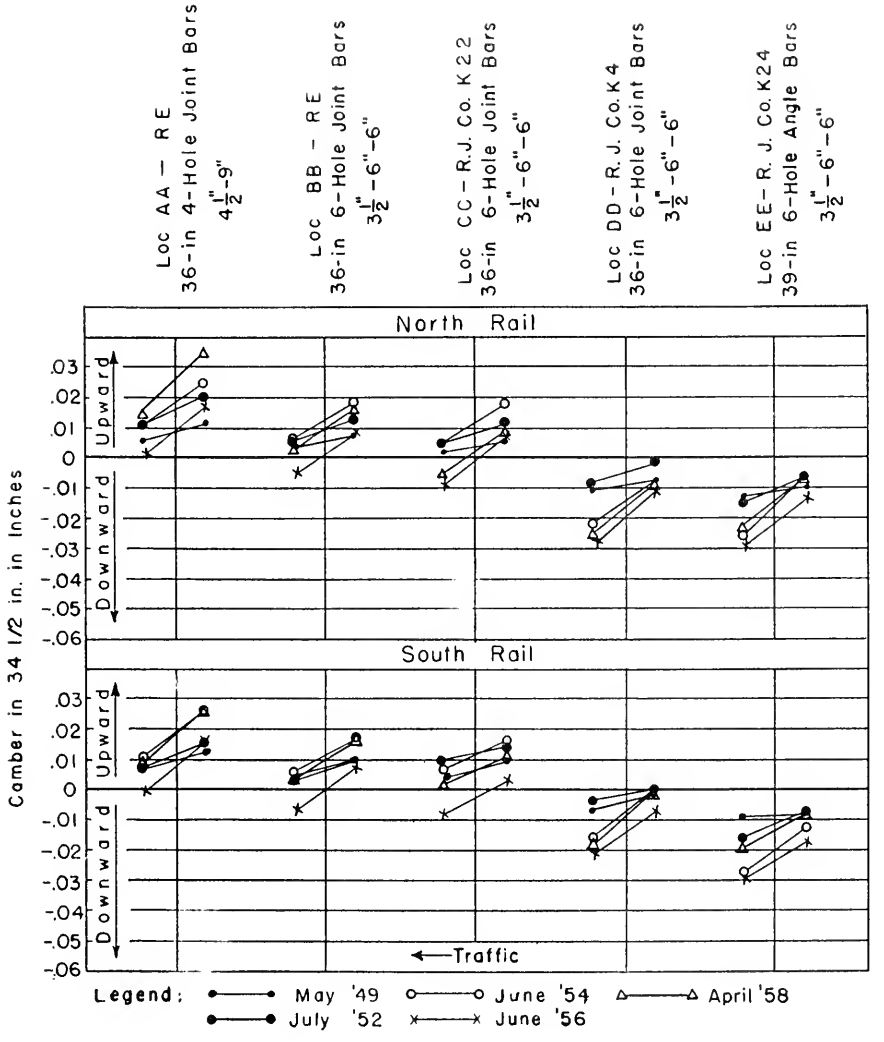
Note. Profile elevations are the average of 15 joints in each rail.

Fig. 4. Rail Surface Profile, A.T.&S.F. Ry, 1948 to 1958



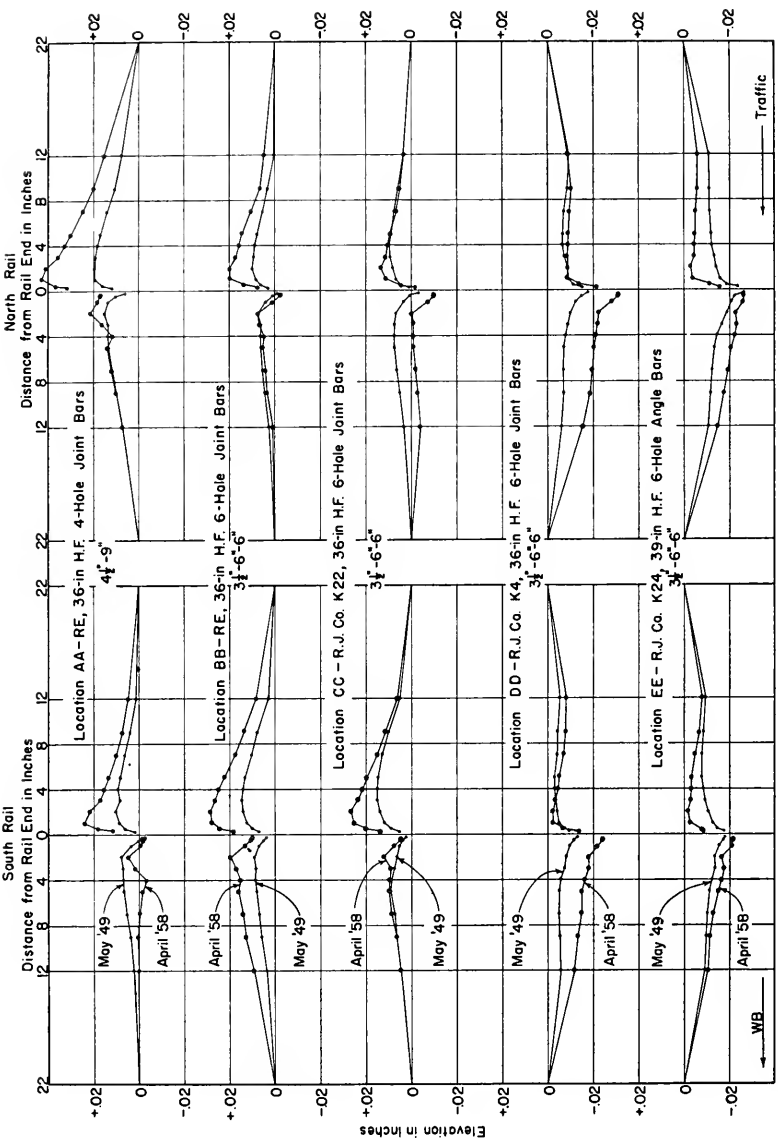
Note: Out-to-Out measurements are the average of 30 joints in each rail at all test locations.

Fig. 5. Change in Out-to-Out Distances at Middle of Joint Bars, AT&SF Ry.



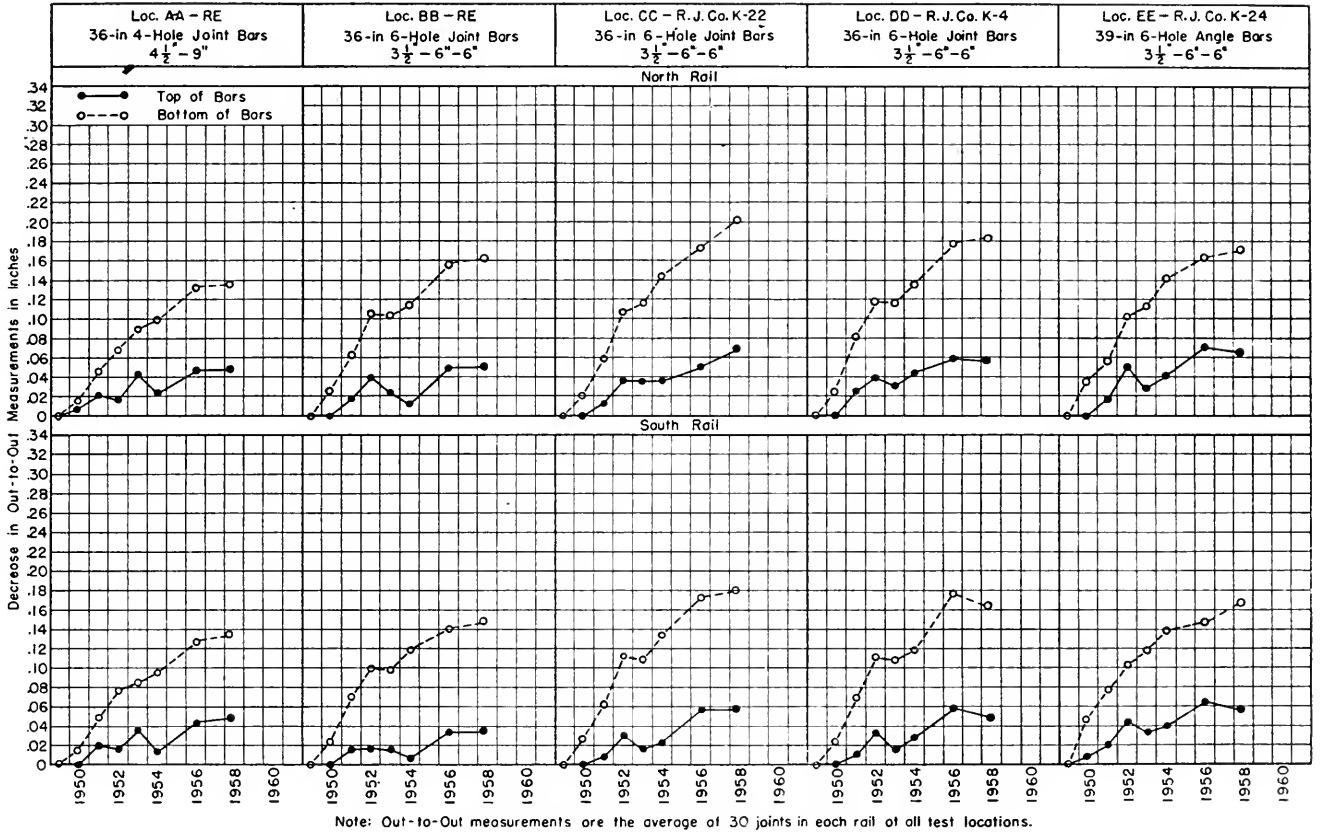
Note: Camber readings are the average of 30 joints each of North and South rail of all test locations, taken 1/2 in. from rail ends.

Fig. 6. - Top of Rail Camber in 34 1/2 in., C&NW Ry. 1949 to 1958



Note: Profile elevations are the average of 15 joints in each rail.

Fig. 7. Rail Surface Profile, C.&N.W. Ry. 1949 to 1958



Note: Out-to-Out measurements are the average of 30 joints in each rail at all test locations.

Fig. 8. Change in Out-to-Out Distances at Middle of Joint Bars, C&NW Ry.

Report on Assignment 7

Joint Bar Wear and Failures; Revision of Design and Specification for New Bars, Including Insulated Joints, and Bars for Maintenance Repairs

Embert Osland (chairman, subcommittee), S. H. Barlow, G. V. Begany, Jr., T. A. Blair, Blair Blowers, R. M. Brown, J. A. Bunjer, C. A. Colpitts, C. O. Conatser, L. S. Crane, W. J. Cruse, C. E. R. Haight, V. E. Hall, C. J. Henry, W. H. Hobbs, S. R. Hursh, C. E. Morgan, G. L. P. Plow, J. F. Shaffer, S. H. Shepley, H. F. Whitmore, W. L. Young.

This is a progress report, presented as information:

Research work directed towards the development of an improved head easement for joint bars has been completed, and a new drawing showing the recommended head easement is being presented for adoption and publication in the Manual under Assignment 1.

Work is being continued in developing methods directed towards evaluating improved designs of insulated joints.

Report on Assignment 8

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention

W. H. Hobbs (chairman, subcommittee), W. D. Almy, F. W. Biltz, T. A. Blair, B. Bristow, T. F. Burris, C. J. Code, C. O. Conatser, L. S. Crane, W. J. Cruse, C. J. Henry, S. R. Hursh, W. M. Jaekle, K. K. Kessler, C. C. Lathey, R. F. Lawson, W. B. Leaf, Lee Mayfield, Ray McBrian, B. R. Meyers, L. T. Nuckols, J. G. Roney, J. S. Wearn, Edw. Wise, J. E. Yewell.

This is a progress report, presented as information.

During the past year this investigation has been limited to that conducted by (a) the Engineering Division research staff, AAR; (b) Pennsylvania Railroad; (c) the University of Illinois, and (d) the Joint Contact Committee, AREA–AISI. The report on another three-dimensional photoelastic investigation by Dr. M. M. Frocht, which relates to the shelly rail failure, is also included as information.

The AAR provides funds to support the work performed by its Enginereing Division research staff, and the AAR and AISI jointly provide funds to support the work conducted by the University of Illinois.

The Joint Contact Committee, consisting of members selected by the Rail committee and by the rail manufacturers, has met during the past year with the research investigators for the purpose of reviewing and guiding the conduct of the research work.

That portion of the work conducted by the AAR Engineering Division research staff is covered by a report submitted by Kurt Kannowski, metallurgical engineer, which is included in this report as Appendix 8–a. It covers inspections of service tests of heat-treated and alloy rail installations at 11 locations. There are six tests of heat-treated rail, four of chrome–vanadium alloy, three of high-silicon rail, and one of flame-hardened rail.

The necessity of increasing the service life of rail on 2 to 6-deg curves from 9 to 12 months to 2 to 3 years has become very desirable. Standard carbon rail on the low side

of curves at certain locations has had a life of only 9 months and has failed because of excessive head flow. This same rail on the high side has had a life of 18 months and has failed from shelling.

In service tests on various curves with previous histories of shelling and head flow, the use of fully heat-treated rail, chrome–vanadium alloy rail, high-silicon alloy rail, and flame-hardened rail has lengthened the service period extensively, both on the high and low sides of curves. In the case of the low rail, using heat-treated rail, the life has been extended by 5–6 times and in the case of the high rail by 2–3 times. The chrome–vanadium alloy rail has given the same performance to a slightly lesser degree.

Further observations of the service tests will develop more information. A trend of better service performance of the high-silicon alloy rail installation has also been observed. Insufficient tonnage over these installations at this date precludes any conclusions. Even though some advantage of the flame-hardened rail over the standard rail could be noted, definite conclusion from the one installation could not be drawn. Individual practices of the various railroads in rail laying on these curves influence the above results.

The final report of service tests of 155-lb heat-treated rail on the Pennsylvania Railroad laid on the high side of a 6-deg curve in the eastward passenger and freight track east of Tyrone, Pa., prepared by C. J. Code, is included in this report as Appendix 8–b. The following conclusions may be drawn from this report:

1. Under the conditions encountered in this test, heat-treated rail is more resistant to shelling than ordinary rail, although not completely resistant. It is credited with giving 50 percent more life than non-heat-treated rail. It also shows some improvement in resistance to flange wear.
2. With the present extra for heat treating there is little to be gained by the use of heat-treated rail on this location. Its use can probably generally be justified where an increase in life of 50 percent or more can be obtained.
3. The rail end condition was better for the end-hardened, non-heat-treated rail. For locations where rail end condition becomes the controlling factor in rail renewals, the use of heat-treated rail will probably not be justified.
4. It is recommended that further consideration be given to the use of heat-treated rail at locations where a moderate type of shelling takes place, but to such an extent as to constitute an important factor in the life of rail.

Attention is directed to the fact that these conclusions are drawn from one test of quite limited extent, and under somewhat special conditions. Results reported elsewhere on tests of heat-treated rail on other roads have been considerably more favorable. There are locations where its use can be justified, such as have been reported by this committee on the Norfolk & Western and Great Northern Railroads, where the life of the rail in the curves had been extended from 4 to 6 times by the use of heat treatment. The test on the Great Northern is still in progress.

That portion of work conducted by the University of Illinois is covered by a report prepared by Prof. R. E. Cramer, which is included in this report as Appendix 8–c.

This report covers the results of (1) rolling-load tests to produce shelling in chrome–vanadium alloy rails, (2) rolling-load tests to produce shelling in high-silicon and extremely high-silicon rails, (3) rolling-load tests to produce shelling in induction-hardened rails, (4) shelling produced in service, and (5) rolling-load tests to produce detail fractures.

Prof. Cramer summarizes his report as follows:

1. Laboratory tests of chrome–vanadium rails give high cycles for failure but with considerable scatter in results.
2. Rolling-load tests are reported on 6 extremely high-silicon rails with 1.63 percent silicon. These specimens did not give as good results as previous tests on rails with less than 1 percent silicon content.
3. Rolling-load tests are reported on six induction-hardened rails furnished by Teleweld, Inc. These hard rails resist flow or abrasion on the gage corner but develop shelling cracks in the laboratory tests sooner than standard carbon-steel rails.
4. Pictures are shown in Fig. 4 of shelling produced in service.
5. One rail, laboratory No. 995, was examined which had developed complete fractures in service at two detail fractures from shelling only 32 in apart in the rail. This emphasizes the necessity of careful detector car tests of rails for detail fractures.
6. Two detail fractures from shelling were produced in laboratory rolling-load tests of 136-lb chrome–vanadium rails with Brinell hardness of 368 and 373. These two rails ran 2,827,900 and 9,258,500 cycles. This again shows the variations obtained in laboratory tests of chrome–vanadium rails but also emphasizes that some tests last five or more times as long as standard carbon-steel rails.

That portion of the work conducted by the Joint Contact Committee, AREA–AISI, is covered by report prepared by L. H. Winkler, which is included in this report as Appendix 8–d. It covers "Investigation into the Significance of the Hydrogen Level in Rail Steel."

Hydrogen determinations were made on random samples of rails taken from current mill production and also on rails that have developed shelly spots in service These tests fail to show hydrogen content in any significant amounts and indicate no evidence that hydrogen contributes to shelling.

The final report on another three-dimensional photoelastic investigation by Dr. M. M. Frocht to study the internal stresses within the rail head due to wheel contact pressures is presented in Appendix 8–e. This investigation was conducted under the sponsorship of the AAR Joint Committee on Relation Between Track and Equipment and is included with the permission of the Joint Committee. The first report on this subject, made by Dr. Frocht in June 1953, was published in the Rail committee report, Vol. 55, page 854. It included stress determination directly under the wheel only. Subsequent study indicated the possibility that more critical stresses, taking into account the range of stress and amount of stress reversal, might occur in the rail a short distance preceding or following the center of the wheel contact pressure. As is shown in Dr. Frocht's report, this condition was found to be true, and the diagrams presented in his report give information on the range of stress, both direct and shearing stress, resulting from the wheel contact pressure along the length of the rail. Also, Dr. Frocht has translated the model stresses into the equivalent stresses in the full-size wheel and rail, and from these has concluded for the conditions of his study with a typical worn wheel and rail contour, and 33-in diameter wheel, that "a wheel load of 30,000 lb would seem sufficient to put the rail in a state of incipient failure."

Appendix 8–a

Report on Service Tests of Heat-Treated and Alloy Rail

The following report was prepared by Kurt Kannowski, metallurgical engineer of the AAR Engineering Division research staff, under the general direction of G. M. Magee, director of engineering research.

1. Chesapeake & Ohio Railway Service Test of 132-lb Heat-Treated Rail

This test installation is described extensively in the AREA Proceedings, Vol. 57, page 833. The 12 heat-treated (oil quenched) and the 12 non-heat-treated, end-hardened rails near Martha, W. Va., were inspected May 6, 1958. These 132-lb RE rails were laid in the high and low sides of the northbound (loaded) track in a 3-deg 6-min curve on May 2, 1949.

The test rails have carried approximately 240,000,000 gross tons of traffic to date. The only test rail without gage corner developments is the heat-treated rail 87581–D–11. Head checks and black areas as well as distinct black spots appear in the other five heat-treated rails. The non-heat-treated rail 87581–C–37 was turned end for end on April 3, 1958, changing the field side to gage side. The change was made because of the severe shelling. This is the first change in rails on this test installation. Two more of the non-heat-treated rails have developed shells, and three had flaking and black spots.

Both the heat-treated and non-heat-treated rails in the low side of the curve are in excellent condition, with slightly more plastic flow on the non-heat-treated rails. Developments of gage corner defects have been relatively slow on this test installation. All of the developments are high on the gage corner.

2. Norfolk & Western Railway Service Test of 132 RE Heat-Treated Rail at Kermit

A final report on the service test of the 132 RE heat-treated rail at Kermit, W. Va. was given in 1957 and may be found in the Proceedings, Vol. 58, pages 1030–1032. Since 8 of the original 12 heat-treated rails on the high side and 10 of the original 11 in the low side of the curve are still in service, an inspection was made on May 7, 1958. The remaining heat-treated rails are, generally speaking, in better condition than the adjacent non-heat-treated replacement rails in both the high and low sides of the curve. In the high side this is the third set of non-heat-treated rails while in the low side it is the fifth set. These remaining test rails had carried an estimated 389,000,000 gross tons of traffic at the inspection date. The heat-treated rail 87581–D–13 on the high side of the curve still shows no development of gage corner defects. Flaking, black spots, and shelling in various combinations are noted on the remaining rails on the high side. Only a slight progression of the defects over last year's condition could be noted.

The condtion of the rails on the low side of the curve is good.

3. Norfolk & Western Service Test of 132-Lb RE Heat-Treated Rail At Maher and Looney's Curve

These installations on a 6-deg curve near Maher, W. Va., at M. P. 481 + 210 ft and on the 4-deg, 7-deg, 12-deg Looney's Curve at M. P. 455 + 582 ft are described extensively in the AREA Proceedings, Vol. 57, pages 834–835.

Fifty-five heat-treated (oil quenched) rails were laid on the high side and 54 on the low side of Looney's curve. The test rails had carried approximately 85,000,000

gross tons of traffic at the inspection date, May 8, 1958. The curve oiler was not operating very efficiently at this time.

In the high side of the curve, 24 of the rails are free of gage-corner developments, while light flaking was noted on 18 and head checks on 3 of the rails. Of the remaining 10 rails, 3 had black spots and 7 had small shells. There has been a progression of the gage-corner developments on the high and on the low side since last year's inspection. It is of interest that after 45 months of this type of service the rails appear relatively good, while non-heat-treated rails in this location had lasted only 15–18 months on the high side and 6–9 months on the low side.

Sixty-six heat-treated rails were installed in both the high and low sides of the 6-deg curve at Maher, W. Va. These test rails had carried 149,000,000 gross tons of traffic to May 1, 1958. There has been a progression of gage-corner developments since last year in that 27 rails have medium flaking, 10 rails have heavy flaking, 6 rails have black spots, and 1 is shelled.

One heat-treated rail, 81033–F–18, was removed from service prior to the 1957 inspection due to a detected defect by a Sperry rail inspection car. Another heat-treated rail, 87062–D–35, was removed from service in the past year for a similar reason. Both rails were from the high side of the curve.

4. New York Central System Service Test of 127-Lb DY Chrome–Vanadium, Heat-treated and Flame-Hardened Rails at Cedar Run, Pa.

This installation on the New York Central System in the 7-deg 51-min curve No. 242 near Cedar Run, Pa., consisting of 127-Lb DY chrome–vanadium, heat-treated and flame-hardened rails is extensively described in the Proceedings, Vol. 59, pages 957–958. The rails were installed to compare the resistance to abrasion as well as the resistance to shelling of these different metallurgies of rail steel.

At the time of this year's inspection in May, this installation had carried 142,541,000 gross tons of traffic.

In the high side of the curve, one flame-hardened rail had light flaking on half of its length, one chrome–vanadium rail had two locations of small flaking spots while another chrome–vanadium rail had a very small shell. No other gage-corner developments were observed.

In the low side of the curve there has been considerable plastic deformation, with more flow in the standard open-hearth and flame-hardened rails than in the chrome–vanadium or heat-treated rails.

The curve wear has been heavy on most of the test rails, and wheel flanges are contacting the joint bars at the joints of the standard open-hearth and flame-hardened rails. This condition existed last year, but the expected removal of these test rails was postponed due to a change in the maintenance of way program.

5. Pennsylvania Railroad Service Test of 155-Lb PS High-Silicon Rail

This test installation consists of 155-lb PS high-silicon and standard carbon rails on the 2-deg 37-min Bixler curve near M.P. 164 east of Lewiston, Pa. An extensive description can be found in the Proceedings, Vol. 53, page 1029.

The test rails had carried approximately 110,000,000 gross tons of traffic at the inspection date in May 1958. The high-silicon and the standard-analysis rails had comparable light to medium flaking throughout the part of the curve which was at full elevation. The test rails on the tangent of the receiving end of the curve showed no gage-corner developments.

A slightly heavier amount of flange wear was observed on the standard-analysis rails of the high side.

6. Pennsylvania Railroad Service Test of 140 PS Chrome–Vanadium Alloy Rail

This test of 140 PS chrome–vanadium rail is described extensively in the Proceedings, Vol. 58, pages 1029–1030. It consists of 31 chrome–vanadium rails on the high side interspersed with standard control-cooled rails and 16 chrome–vanadium rails interspersed with standard control-cooled rails on the low side of a 3-deg 52-min curve east of Torrance, Pa.

During this year's inspection at 110,000,000 gross tons of traffic it was noted that very little change since last year had taken place. Two of the chrome–vanadium rails had a black spot each—about 3 in long on one and 1½ in long on the other. No other gage-corner developments could be found. The standard rails had one rail with three shells and another with two shells. Head checks and medium flaking were observed on all of these rails.

7. Pennsylvania Railroad Service Test of 140-Lb RE High-Silicon Rail

This test installation of high-silicon 140-lb RE rail on the Mifflin Reverse Curve, Stone House Curve and Casner's Curve between M.P. 152 and M.P. 153 in No. 4 track east of Mifflin, Pa., was installed in 1956. At this year's inspection in May 1958 insufficient traffic had been carried to indicate any trend in gage-corner developments.

8. Service Test of Chrome–Vanadium and High-Silicon 136-Lb CF&I Rail on the Southern Pacific Company

At the request of W. M. Jaekle, chief engineer of the Southern Pacific Company, an inspection of the service test installations of the chrome–vanadium and high-silicon 136-lb CF&I section was made in May 1958 in conjunction with a representative of the steel producer. Since these types of alloy rails have shown considerable resistance to shelling on other installations, it was considered to be of interest to obtain the contours and data shown on Figs. 1 to 6, incl., from the Southern Pacific. Data obtained on other test installations with a history of shelling has been on 2 up to 6 deg curves. All of the curves on this service test are from 10 to 10 deg 10 min. These curves are on single track on the San Joaquin Valley Line of the Tehachapi District with a 1.85 to 2.20-percent grade and an elevation of 3 in. The maximum authorized speed in this area is 25 mph. The life of the carbon rail with transposing is 18 months on the average, with an approximate annual tonnage of 44,000,000.

The chrome–vanadium alloy rails were produced by the Colorado Fuel and Iron Corporation in the 136-lb CF&I section. The chemical analysis of the two heats is as follows:

Heat No.	*Carbon*	*Manganese*	*Phos.*	*Sulfur*	*Silicon*	*Chrome*	*Vanadium*
5–263	0.76	1.46	0.019	0.024	0.29	0.83	0.15
7–270	0.77	1.45	0.030	0.026	0.31	0.83	0.13

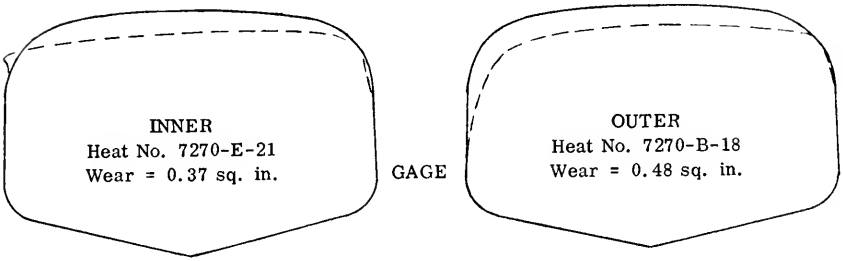
The high-silicon rails were produced by the Colorado Fuel and Iron Corporation in the 136-lb CF&I section. The chemical analysis of the three heats is as follows:

Heat No.	*Carbon*	*Manganese*	*Phosphorus*	*Sulfur*	*Silicon*
4–257	0.77	0.89	0.016	0.024	0.69
3–275	0.73	0.85	0.020	0.020	0.71
11–277	0.73	0.81	0.027	0.028	0.57

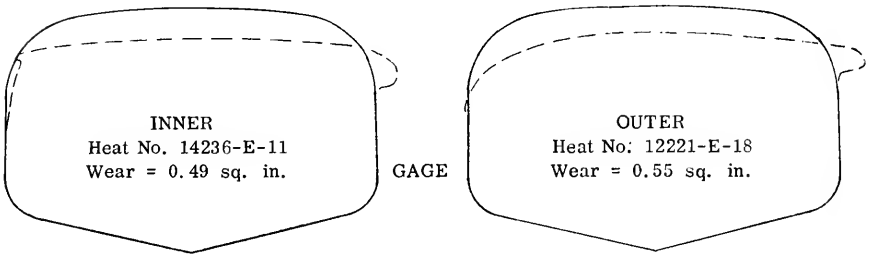
(Text continued on page 928)

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

Chrome Vanadium Rail



Regular Carbon Rail

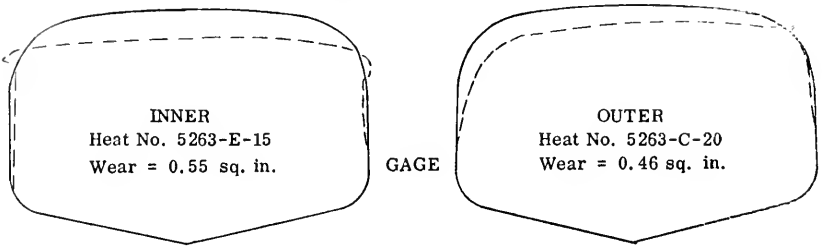


10° 00' Curve + 2.20 Percent Grade - Milepost 349.71 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 77

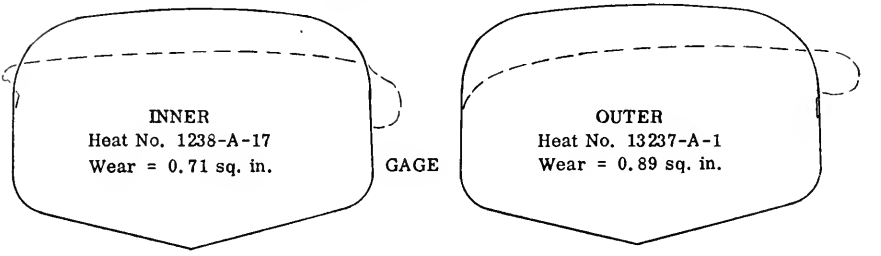
FIG. 1

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

Chrome Vanadium Rail



Regular Carbon Rail

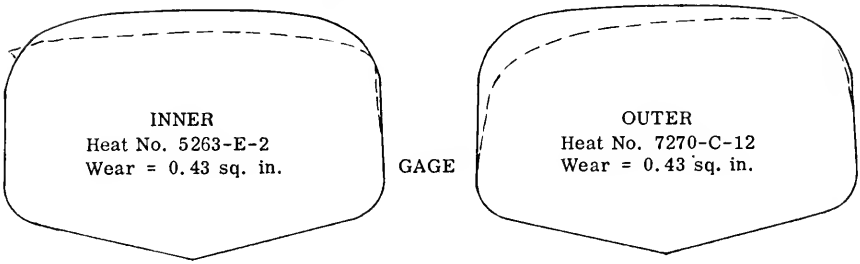


10° 10' Curve + 2.08 Percent Grade - Milepost 355.15 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 98

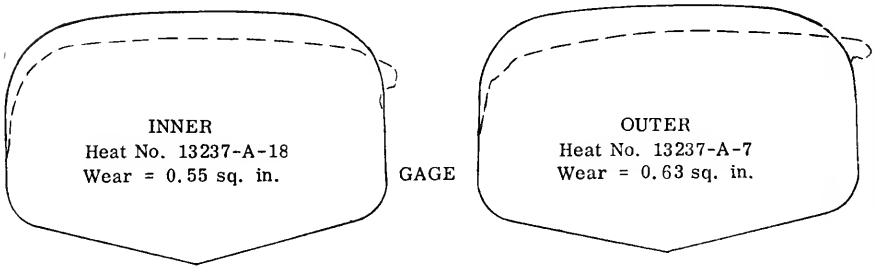
FIG. 2

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

Chrome Vanadium Rail



Regular Carbon Rail

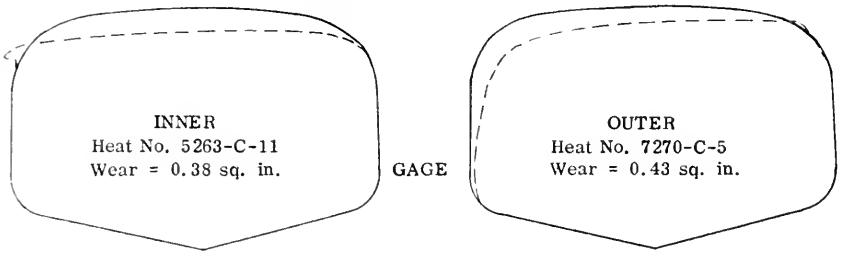


10° 07' Curve +1.825 Percent Grade - Milepost 359 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 122

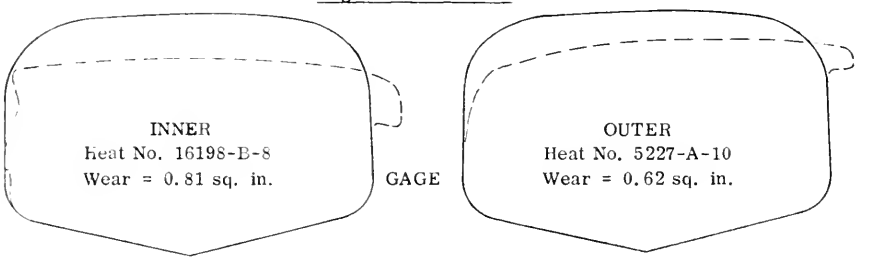
FIG. 3

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

Chrome Vanadium Rail



Regular Carbon Rail

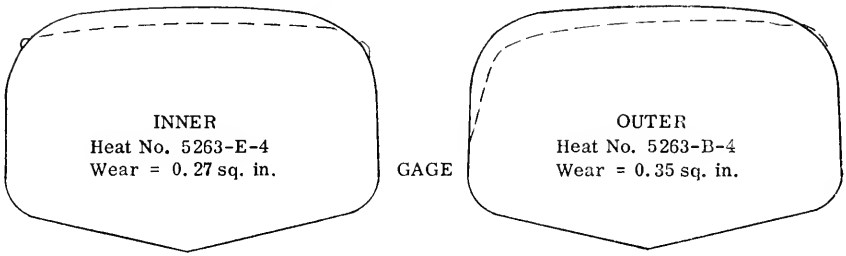


10° 02' Curve + 2.02 Percent Grade - Milepost 344.61 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 57

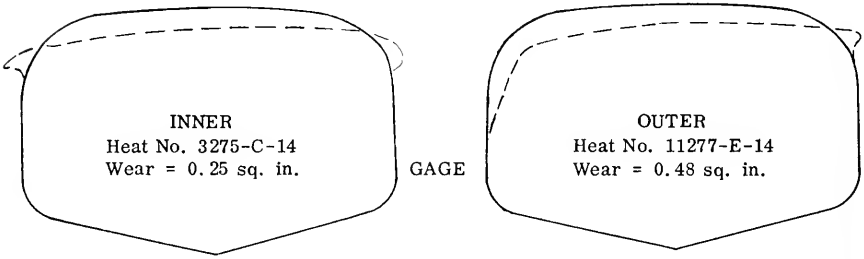
FIG. 4

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

Chrome Vanadium Rail



High Silicon Rail

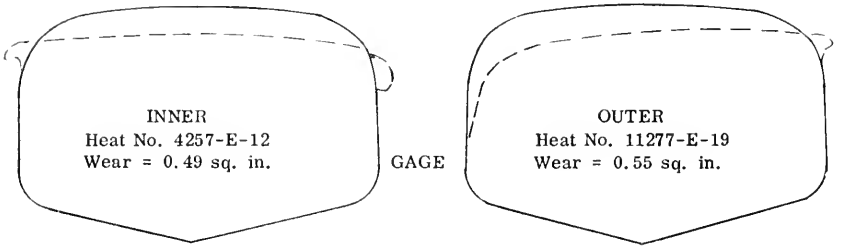


10° 10' Curve +2.00 Percent Grade - Milepost 337.79 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 25

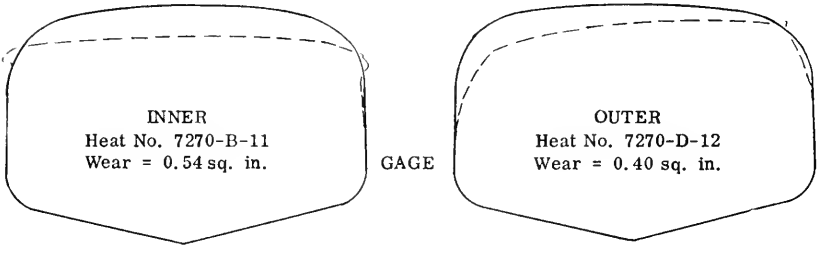
FIG. 5

RAIL CONTOURS
SOUTHERN PACIFIC COMPANY
SAN JOAQUIN VALLEY LINE - TEHACHAPI DISTRICT
MAY 1958

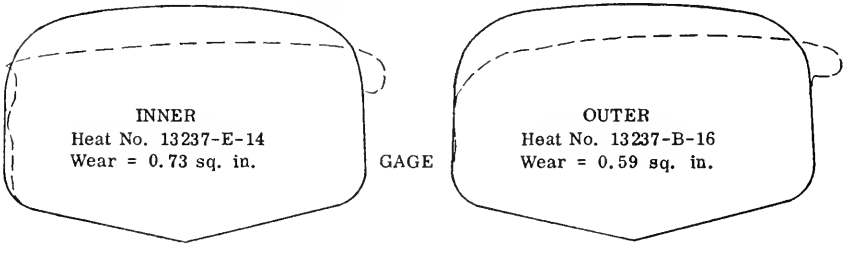
High Silicon Rail



Chrome Vanadium Rail



Regular Carbon Rail



10° 00' Curve + 2.12 Percent Grade - Milepost 354.79 - 136 CF&I Section
Rolled: 4-56 Laid: 5-56 Traffic Carried: 89 Million Gross Tons
Curve 96

FIG. 6

At the time of the inspection 89,000,000 gross tons of traffic had passed over the test installations and the carbon rail had been transposed. It can be noted on Figs. 1–4 comparing the chrome–vanadium rails to the carbon rails that there is a considerable difference in the wear and the head flow between the two metallurgies. Of further interest in these test installations is curve 25. Fig. 5 shows the contours of chrome–vanadium rail on this curve compared to high-silicon rail. This curve shows a considerable better wear performance for the high-silicon rail compared to carbon rail as well as a very good performance for the chrome–vanadium. Fig. 6 shows the contours of chrome–vanadium rail compared with high-silicon and carbon rail on curve 96. From this it again can be noted that the high-silicon and chrome–vanadium rail give considerably better head flow and wear performance. The apparent lack of metal flow noted on the chrome–vanadium alloy rail on the low side is not an indication of absence of head wear. In the case of the low rail on this particular installation the wear of the high-silicon rail is better than that of the chrome–vanadium rail.

During this inspection no gage-corner development leading to shelling was observed. Curve lubrication is not used because sanding on the grades is necessary. The economic feature of the resistance to abrasion and head flow of the low rail makes these installations of considerable interest.

9. Duluth, Missabe & Iron Range Railway Service Test of Chrome–Vanadium Alloy Rail

This installation is described extensively in the Proceedings, Vol. 57, page 833.

At the date of this year's inspection, October 15, 1958, 108,000,000 gross tons of traffic had passed over the curves at M. P. 3.93, M. P. 3.58, M. P. 32.2 and M. P. 26.65. The standard carbon rail on curves M. P. 3.93 and M. P. 3.58 had been removed on account of shelling at approximately 90,000,000 gross tons of traffic. The chrome–vanadium rail showed very little change at this location as well as at M. P. 32.2. The standard carbon rail at this location had been removed at approximately 89,000,000 gross tons of traffic on account of shelling. The replacement carbon rail at any of these locations did not show any gage-corner defects connected with shelling at this date.

The curve at M. P. 26.65, which is characteristic due to removal of rail on account of abrasion, still had the chrome–vanadium rail in track showing evidence of abrasion and very little of head checks. The carbon rail had been removed in the spring of 1957 on account of shelling and abrasion at approximately 65,000,000 gross tons of traffic.

Curve oilers were noted to be in operation at the time of the inspection.

10. Great Northern Railway Service Tests of 115 RE Heat-Treated Rail

This installation is extensively described in the Proceedings, Vol. 57, pages 837–850.

The 115-lb RE section test rails were put into service in two comparable curves on February 7, 1951, East of Carlton, Minn. As mentioned in previous reports, 88 heat-treated rails were installed in both the high and low sides of the 4-deg curve No. 20, and 88 non-heat-treated, end hardened rails in the high and low sides of the 4-deg curve No. 22 for comparison. The heat-treated rails were from heat 89521 rolled at Steelton in November 1950 and were oil quenched and tempered. The comparative non-heat-treated rails were supplied by Illinois and were field end hardened.

The original non-heat-treated test rails in the high side of curve No. 22 were replaced August 1, 1955, after carrying 193,000,000 gross tons of traffic, because of extensive shelling and at least one rail had failed in service from a detailed fracture from shelling. The original non-heat-treated test rails in the low side of No. 22 curve

as well as the heat-treated test rails in both the high and low sides of curve No. 20 were all in service at the time of this inspection and had carried 316,212,670 gross tons of traffic to October 14, 1958.

Considerably more and heavier flaking was in evidence in this second set of non-heat-treated rails in the high side of curve No. 22 than in the original heat-treated rails in the high side of curve No. 20 at the time of this inspection. This was true in spite of the fact that the heat-treated rails had carried 123,212,670 additional gross tons. In the low side of curve No. 22 the original non-heat-treated rails were badly crushed and very rough. A considerable amount of plastic deformation of the head metal had resulted in heavy fins on the field side of the head of these rails.

Very little change has taken place in the majority of the test rails of curve No. 20. Six shelling spots were observed in rail 89521–G9 and one small shell in rail 89521–F10. Shelling was noted in both rails last year. An additional rail, 89521–E4, was found to contain one shell this year.

There appeared to be an increase in the curve wear in portions of the curve which would account for the decrease in amount of head checks and the changes in flaking conditions noted in certain rails. The curve oiler was in operation at the time of the inspection.

The heat-treated rails in the low side of the curve were found to be in excellent condition. The resistance to wear and plastic flow has been outstanding.

Appendix 8-b

Final Report on the Service Test of the 155-Lb Heat-Treated Rail on the Pennsylvania Railroad

By C. J. Code
Assistant Chief Engineer—Staff, Pennsylvania Railroad

The test was installed on the Pennsylvania Railroad in order to determine whether heat-treated rail is more resistant to shelling than ordinary control-cooled rail. Twelve 155-lb PS 39-ft, heat-treated rails and twelve 155-lb PS 39-ft, control-cooled, end-hardened rails were obtained from the same heats for this test. The rails were manufactured and heat treated at the Steelton plant of the Bethlehem Steel Company. The heat-treated rails cost $171 each. At that time the price of standard control-cooled, non-heat-treated rail was $65 per net ton, or $67 per rail, including end hardening.

The rails were laid on the high side of No. 11 Curve, a 6-deg curve in No. 1 eastward passenger and freight track, Altoona District, Pittsburgh Region, east of Tyrone, Pa., on January 19, 1949. The heat-treated and non-heat-treated rails were laid in alternate stretches of two rails each. Laboratory examinations were made of two samples of rail from the heats laid in this test, one heat treated and one not heat treated. Measurements of Brinell hardness of the rails were taken before the rails were laid. Measurements of rail head abrasion, track gage and cross level were taken when these rails were laid and periodically until transposed in 1956. Photographic records of visual inspections were made to show the progress of the shelly condition. Observations made during the annual inspections by representatives of the railroads, the producer and the AAR research staff are reported in AREA Proceedings, Vols. 51 to 58.

The results of the laboratory examination of the heat-treated and non-heat-treated rail are summarized in Table 1. The Brinell hardness on all of the rails was obtained with a King portable hardness tester after removal of decarbonized metal with the following results:

	Brinell Hardness		
	Max	*Min*	*Avg*
Heat treated	388	331	362
Standard	302	241	280

Rail head abrasion, average track gage and superelevation are listed in Table 2. Due to the fact that the rail in this test was inadvertently surface ground in 1953, the head abrasion data are presented separately for the periods before and after grinding.

TABLE 1—RESULTS OF CHEMICAL AND PHYSICAL TESTS OF HEAT-TREATED AND NON-HEAT-TREATED RAIL

Chemical Analysis

	HT 88V507–E–10	*CC 82V510–B–5*
Carbon	0.79%	0.77%
Manganese	0.96%	1.00%
Phosphorus	less than 0.030%	less than 0.030%
Silicon	0.173%	0.187%
Sulfur	0.022%	0.030%
Chromium	not found	not found
Nickel	not found	not found
Copper	0.13%	0.15%
Vanadium	not found	not found
Molybdenum	not found	not found

Tensile Test, Standard 0.505 x 2-In Specimens Taken at Standard Location

	Load, PSI		Elongation	Reduction of Area
	Yield Point	Tensile Str.	in 2", Percent	Percent
HT 88V507—"O"	126100	177400	14	34.5
HT 88V507—"M"	119600	158600	16	36.5
CC 82V510—"O"	87630	142400	12	17.0
CC 82V510—"M"	86940	141600	11	13.5

Brinell Hardness at Standard Locations

	1	2	3	4	5	6	7	Average
HT 88V507	341	351	340	311	321	351	351	340
CC 82V510	286	277	277	269	277	286	286	279

TABLE 2—RAIL HEAD ABRASION OF HIGH RAIL, TRACK GAGE, AND SUPERELEVATION ON 6-DEG CURVE NO. 11, NO. 1 TRACK, ALTOONA DISTRICT, EAST OF TYRONE, PA.

Type of Rail	Before Grinding Feb. 1949 to Apr. 1953 218 Mil. Gross Tons			After Grinding Oct. 1953 to July 1956 140 Mil. Gross Tons			Total 358 Mil. Gross Tons		
	Sect. Area Abraded (Sq In)	Avg. Trk. Gage (In)	Avg. Super-elevation (In)	Sect. Area Abraded (Sq In)	Avg. Trk. Gage (In)	Avg. Super-elevation (In)	Sect. Area Abraded (Sq In)	Avg. Trk. Gage (In)	Avg. Super-elevation (In)
Std.	0.32	56 3/4	3 1/8	0.41	57	2 5/8	0.73	56 7/8	2 7/8
H.T.	0.38	56 7/8	4 1/2	0.13	57	4 1/2	0.51	56 7/8	4 1/2
Std.	0.32	56 7/8	6 3/8	0.39	57 1/8	6	0.71	57	6 1/4
H.T.	0.24	56 7/8	6 3/8	0.23	57	6 1/4	0.47	56 7/8	6 3/8
Std.	0.31	56 7/8	6 1/4	0.41	57 1/8	6 1/8	0.72	57	6 1/4
H.T.	0.27	56 3/4	6 1/4	0.18	56 7/8	6 1/8	0.45	56 3/4	6 1/4
Std.	0.31	56 7/8	6 3/8	0.31	57	6 1/4	0.62	56 7/8	6 3/8
H.T.	0.29	57	6 1/8	0.38	57 1/8	5 7/8	0.67	57	6
Std.	0.37	56 7/8	5 1/4	0.60	57 1/4	5 1/8	0.97	57	5 1/4
H.T.	0.21	56 5/8	4	0.23	56 7/8	3 5/8	0.44	56 3/4	3 7/8
Std.	0.19	56 3/4	2 5/8	0.14	57	2 1/4	0.33	56 7/8	2 1/2
H.T.	0.23	56 5/8	1 1/8	0.09	56 3/4	7/8	0.32	56 5/8	1
Std.	0.30	56 7/8	5	0.38	57 1/8	4 3/4	0.68	57	4 7/8
H.T.	0.27	56 3/4	4 3/4	0.21	57	4 5/8	0.48	56 7/8	4 3/4

The accompanying photographs, Figs. 1 to 4, incl., show the condition of certain rails as of the final inspection on May 9, 1956. For certain selected rails, additional photographs (Figs. 5 to 8, incl.) are presented which show the condition on earlier inspections beginning with March 7, 1951, and continuing up to June 15, 1955. For these rails the gradual obliteration of the evidence of shelling by flange wear, 1953 to 1956, is worthy of note. A memorandum of an inspection on August 22, 1949, five months after the rail was laid, indicates that at that time the non-heat-treated rail showed slight flaking and some flow. The heat-treated rails showed no flow or flaking, but showed head checks, extending up from the gage corner 3/8 to 1/2 in. The report of the inspection made October 5, 1949, indicates that head checking was wearing off the heat-treated rails; however, heat-treated rail No. 88507–B–12, near the west end of the curve showed flaking. A further inspection on January 13, 1950, showed the same condition, except that the flaking was fairly heavy on rail No. 88507–B–12, and it was observed that this rail was taking an excessive thrust at the beginning of the curve. An inspection on March 9, 1951, developed the following information: on the leaving end of the curve, there was flaking on both heat-treated and non-heat-treated rails, somewhat worse on the non-heat-treated.

Throughout the body of the curve, that is, the fully elevated portion, the heat-treated rails showed less flaking than the non-heat-treated rails, a noticeably better performance. At the west or receiving end of the curve, the heat-treated and non-heat-treated rails both showed heavy flaking. One non-heat-treated rail showed two definite shells, not very large, while one-heat-treated rail showed two black spots. One other non-heat-treated rail showed evidence of a small shell not yet broken out. There was evidence of a sharp spot in the alinement which was probably affecting two of the heat-treated rails adversely. The lubricator was working and the curve was heavily lubricated at this time. The heat-treated rail showed a somewhat better performance than the non-heat-treated rail, and was possibly six months behind the non-heat-treated rail in development of similar defects. It was estimated at the time that some of the non-heat-treated rails would have to be removed in a period of six months to one year. On May 22, 1951, it was noted that there was little change in the condition of the rails; however, the lubricator did not seem to be functioning and there was very little grease on the rail. The shelling condition of the rails of this curve reached a maximum at the time of 1953 inspection. At the time, it was felt that some of the shelly spots were reaching such a size that it would be necessary to renew the rails in the very near future (See Figs. 9 and 10).

Prior to the 1954 inspection, it was indicated to the Division forces responsible for maintenance that it would be agreeable to replace any of the badly shelled rails in the curve, which, in their judgment, should be removed. It was suggested that at that time, in order to get the most life out of the heat-treated rail, and to get the best indication of the relative performance of the heat-treated rail, it would be desirable to patch up this curve with fit rail, having the appropriate amount of flange wear, taking out only those rails on the high side which should be removed because of their shelly condition, regardless of whether or not they are heat-treated or non-heat-treated. No advantage was taken of this proposal by the maintenance forces, and no rails were replaced. There would probably have been justification for renewal at this time of six of the non-heat-treated rails and two of the heat-treated rails due to the stage of the development of shelling. This information is included merely to indicate the relative degree to which the 12 heat-treated rails and 12 non-heat-treated rails had developed shelling at this time.

A review of the inspection reports and the photographs for the 1954, 1955 and 1956 inspections indicates, surprisingly, that the rail condition was getting better instead of worse. Insofar as shelling and flaking were concerned, at the time of the 1956 inspection, many of the shelly spots earlier observed, and some of the heavy flaking, had been reduced by flange wear to the point where they no longer seemd to be an object of concern (Figs. 1–4). Incipient shelly spots in two or three of the heat-treated rails had almost completely disappeared, as shown on Figs. 11 and 12. There were two heat-treated rails near the receiving end of the curve, and possibly three non-heat-treated rails which showed a sufficiently shelled condition of the gage corner to justify removal because of shelling. However, at this time flange wear on the rail had progressed to the point where it was necessary to transpose the rail or to regage the curve, and it was decided to transpose. At this time the condition of the low rail of the curve, which was not the subject of test, was such that it was not suitable for transposal into the high rail so that actually the test rail in the high side of the curve was transposed to the low side, and additional relayer 39-ft rails were provided for laying in the high side.

The 1956 report shows shells or black spots in 6 of the heat-treated rails and 7 of the comparative; flaking in 11 heat-treated and 11 comparative; head checks in

3 of the heat-treated and none of the comparative. Generally,the defects in the comparative rail were of more severe character than in the heat-treated. Table No. 2 shows that the non-heat-treated rail developed about 40 percent more flange wear than the heat-treated rail. Examination of the rail end profile shows that the non-heat-treated end-hardened rails initially had a better profile with adequate camber, and that up to the time of surface grinding after four years of service the non-heat-treated end-hardened rails retained a better profile, and showed less loss of camber. In the final three-year period of service after surface grinding, this effect is less pronounced but is still in evidence.

The rails in this test were laid in pairs of two throughout the length of the curve, alternating two heat-treated rails with two standard rails. This was done for the purpose of getting as nearly equal wear conditions as possible for the two types of rail. It was known from previous tests that the wear conditions and particularly the conditions resulting in shelling vary considerably throughout the length of the curve, also that in many cases the receiving end of a curve in this territory gets harder wear and is more subject to shelling than the leaving end of the curve. There was insufficient rail available to lay two complete curves—one with comparative rail and one with heat-treated rails—and even if this had been possible we probably would not have used this method, in view of the varying conditions from one curve to another even where the curvature, superelevation and authorized speed are nominally the same.

The results obtained on the test, in our opinion, justify the method used. The most severe wear and the most severe shelling took place on the receiving half of the curve; thus rails of both types were subjected to the most severe wear, whereas on the leaving half of the curve, conditions were such that there was less severe wear on rail of both types. This method of laying test rails makes it somewhat more difficult to make an economic determination of the relative life of the rails in the curve; since only a small percentage of the total number of rails in the curve were badly shelled, there was no disposition on the part of the maintenance forces to demand renewal.

However, it can be seen from the information reported in the results that half of the non-heat-treated rails approached a condition where renewal was necessary after four years of service, whereas at this time only two, or 17 percent of the heat-treated rails showed such a condition. These two rails were obviously at a location of unusually severe wear. All rails in the high rail were removed after seven years of service; however this was due to flange wear reaching the point where gaging was necessary rather than due to shelling. If shelling had progressed during the last three years of life of the rail as it did during the first four years, it is probable that the non-heat-treated rail would have been replaced after not more than five years.

It is worthy of note that under the most severe conditions encountered, namely on the receiving end of the curve where the alinement and superelevation were such as to throw an unusual load on the high rail, the heat-treated rails also shelled. They are therefore not proof against shelling under the most severe conditions. Under conditions of shelling somewhat less severe than those encountered in this curve, but sufficiently severe to induce shelling in ordinary open hearth rail, it is probable that a greater difference in relative life of heat-treated compared with non-heat-treated would be developed.

Based on the results of this curve, it is doubtful if heat-treated rail can be credited with more than 50 percent additional life as compared with non-heat-treated rail. Since the extra for heat-treated rail is now such as to make its first cost approximately 50 percent greater than that of non-heat-treated rail, there is apparently but

little to be gained from an economic point of view in installing heat-treated rail under conditions such as existed at this point. The high first cost of installing heat-treated rail presents a considerable obstacle against the use of such rail where there is a limited budget available for rail renewal. There are undoubtedly locations where its use can be justified.

Under conditions such as encountered in this test, heat-treated rail is more resistant to shelling. Its greater resistance is a matter of degree; it is not completely resistant to shelling. It can be expected to give a greater life under conditions contributing to shelling of 50 percent or more. It shows some improvement in resistance to flange wear and, based on the current extra for heat-treated rail, its use is justified where an increase in life of 50 percent or greater can be obtained. Generally, this will obtain on curves where the service is somewhat less severe than on the curve which was the subject of this test.

In relaying the curves in this territory, the greatest economy seems to be obtained by the use of relay rail, which is the current practice.

It is notable that the rail end condition was better for the end-hardened rail than for the heat-treated rail. For locations where rail end condition becomes the controlling factor in rail renewals, the use of the heat-treated rail would not be justified.

It is recommended that further consideration be given to the use of heat-treated rail at locations where a moderate type of shelling takes place, but to such an extent as to constitute an important factor in the life of the rail.

Fig. 1—Heat-treated rail No. 88507–C–11, 358,000,000 gross tons, May 9, 1956.

Fig. 2—Heat-treated rail No. 88507–B–12, 358,000,000 gross tons, May 9, 1956.

Fig. 3—Standard rail No. 82510–C–4, 358,000,000 gross tons, May 9, 1956.

Fig. 4—Standard rail No. 88507–E–12, 358,000,000 gross tons, May 9, 1956.

Fig. 5—Standard rail No. 88507-B-11, March 5, 1951.

Fig. 6—Standard rail No. 88507-B-11, June 15, 1955.

Fig. 7—Heat-treated rail No. 88507–B–12, March 5, 1951.

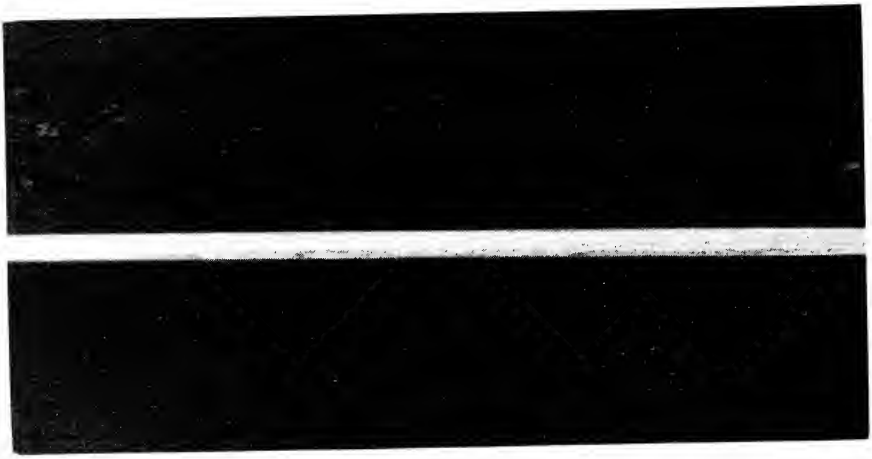


Fig. 8—Heat-treated rail No. 88507–B–12, June 15, 1955.

Fig. 9—Standard rail No. 88507–B–11, May 8, 1953.

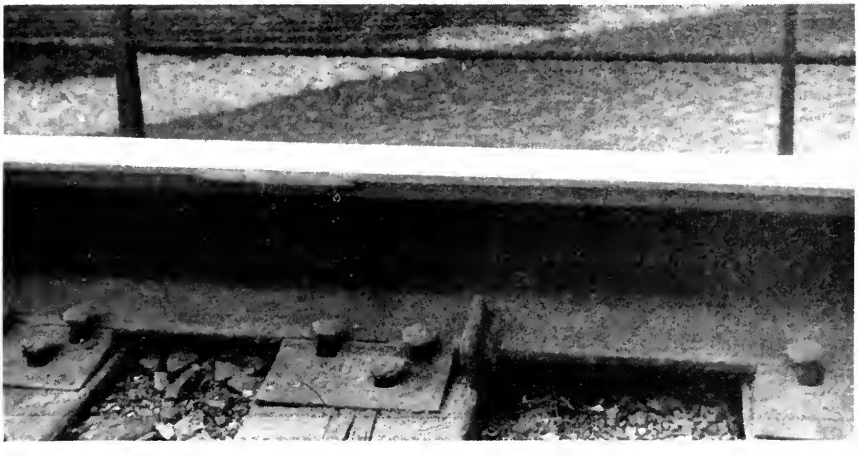


Fig. 10—Heat-treated rail No. 88507–C–13, May 8, 1953.

Fig. 11—Standard rail No. 88507–B–11, 358,000,000 gross tons, May 9, 1956.

Fig. 12—Heat-treated rail No. 82510–E–5, 358,000,000 gross tons, May 9, 1956.

Appendix 8–c

Shelly Rail Studies at the University of Illinois

By R. E. Cramer
Research Associate Professor, University of Illinois

Organization and Acknowledgment

The shelly rail invesigation at this laboratory is financed equally by the American Railway Engineering Association and the American Iron and Steel Institute.

John Finley, student test assistant, worked on this investigation on a part-time basis, and Marion Moore, mechanic, operated the rolling-load machines.

Rolling-Load Tests to Produce Shelling in Chrome–Vanadium Alloy Rails

In last year's report one rolling-load test had been completed on chrome–vanadium rail No. 1183A but the second specimen No. 1183B was not completed. These are both listed in Table 1 where it will be noted that the B specimen ran to 4,509,000 cycles before a shelling crack developed. This is almost double the cycles for the A specimen from the same rail. Laboratory tests of chrome–vanadium rails have generally run around 5 million cycles, but individual specimens have varied over a wide range. This seems to correlate somewhat with experience in service with chrome–vanadium rails as reported by Kurt Kannowski. He has reported a few early failures of chrome–vanadium rails, but most of the test rails are still in service and giving long service similar to most of our laboratory rolling-load tests of these alloy rails. The shelling crack produced in specimen No. 1183B is shown in Fig. 1 and is typical of laboratory-produced shelling failures.

Rolling-Load Tests to Produce Shelling in Extremely High-Silicon Rails

In Table 1 are listed mechanical tests and rolling load tests on three rails, Nos. 1193 to 1195, which are classified as extremely high-silicon rails. These specimens represent a few experimental rails produced with 1.63 percent silicon to determine if a silicon content over 1 percent gave any additional advantages over those rails previously tested with less than 1 percent silicon. The extremely high silicon content of 1.63 percent increased the Brinell hardness to around 320 compared to most high-silicon rails which are between 285 and 305 Brinell. The mechanical strength is higher, but the elongation and reduction of area are lower than previously tested high-silicon rails. The rolling-load cycles average 1,121,700 compared to an average of 1,851,000 cycles for all the high-silicon specimens which have been previously tested.

Figs. 1 and 3 show the types of shelling cracks produced in these extremely high-silicon rails. The B specimen from both rails 1193 and 1194 developed vertical cracks besides the typical shelling cracks without much plastic flow or deformation. This seems to indicate that this steel is more sensitive to cracking than a more ductile silicon steel with less than 1 percent silicon.

It would seem from these tests that no advantage was derived from the extra amount of silicon, and the tests indicate the extremely high-silicon rails develop shelling in the laboratory tests easier than the rails with silicon content below 1 percent.

Rolling-Load Tests to Produce Shelling in Induction-Hardened Rails

In October 1957, Teleweld, Inc., supplied two 12 ft lengths of 132-lb rail that had been experimentally hardened on the gage corner by electric induction to G. M. Magee at the AAR Central Research Center. The description states that the width of the

TABLE 1

MECHANICAL TESTS & ROLLING LOAD TESTS OCT. 1, 1957 - SEPT. 30, 1958

SPEC. NO.	CHEMICAL ANALYSIS C	Mn	Si	Cr	Va	SIZE & KIND OF RAIL	AVE. BRIN. HARD.	YIELD STRENGTH 0.2%	TENSILE STRENGTH psi	ELONG. IN 2" %	RED. OF AREA %	CHARPY VALUE No Notch	CHARPY VALUE Key Hole	ENDURANCE LIMIT psi*	CYCLES FOR FAILURE 50,000 lb WHEEL LOAD
1183A	.77	1.45	31	.83	.13	136 lb Chrome-Va.	368	113,000	175,000	5.7	9.3	128	2.4	L 82,000	2,857,100
B						Colo. for S.P.R.R.								T 61,500	4,509,000
1189A	.82	.84	.67			136 lb High Si.	294	No material available for tests							4,991,000
B			Rail	Ingot		Colo. Bend Tests									3,380,000
1190A	.75	.94	.65	D	I	133 lb Hi. Si.	303	85,300	150,800	7.2	13.7	112	5.2	68,500	4,678,000
B						Colo. for Phelps D									3,380,000
1191A	.75	.94	.65	D	2	133 lb Hi. Si.	304	87,500	152,700	7.3	14.8	121	5.0	70,000	2,055,000
B						Colo. for Phelps D									3,285,000
1193A	.75	.91	1.63	E	3	133 lb Extm. Hi.Si.	321	94,700	160,700	6.0	10.5	122	3.0	74,500	1,562,300
B						Colo. for Phelps D									1,077,000
1994A	.75	.91	163	E	8	133 lb Extm. Hi.Si.	322	98,500	166,300	6.8	12.5	102	3.0	71,000	1,083,300
B						Colo. for Phelps D									1,280,000
1195A	.75	.91	1.63	E	9	133 lb Extm. Hi.Si.	326	97,700	166,300	5.8	10.4	116	3.0	74,750	606,000
B						Colo. for Phelps D									1,015,000
CRH 1A	.74	.86	.17			132 lb Std. Rail Teleweld									803,100
CRH 1B						Gage Corner Induction Hardened									717,800
CRH 2A	.74	.86	.17			132 lb Std. Rail Teleweld									756,100
CRH 2B						Gage Corner Induction Hardened									820,500
CRH 3A	.74	.86	.17			132 lb Std. Rail Teleweld									686,800
CRH 3B						Gage Corner Induction Hardened									592,100

* L - Longitudinal
T - Transverse

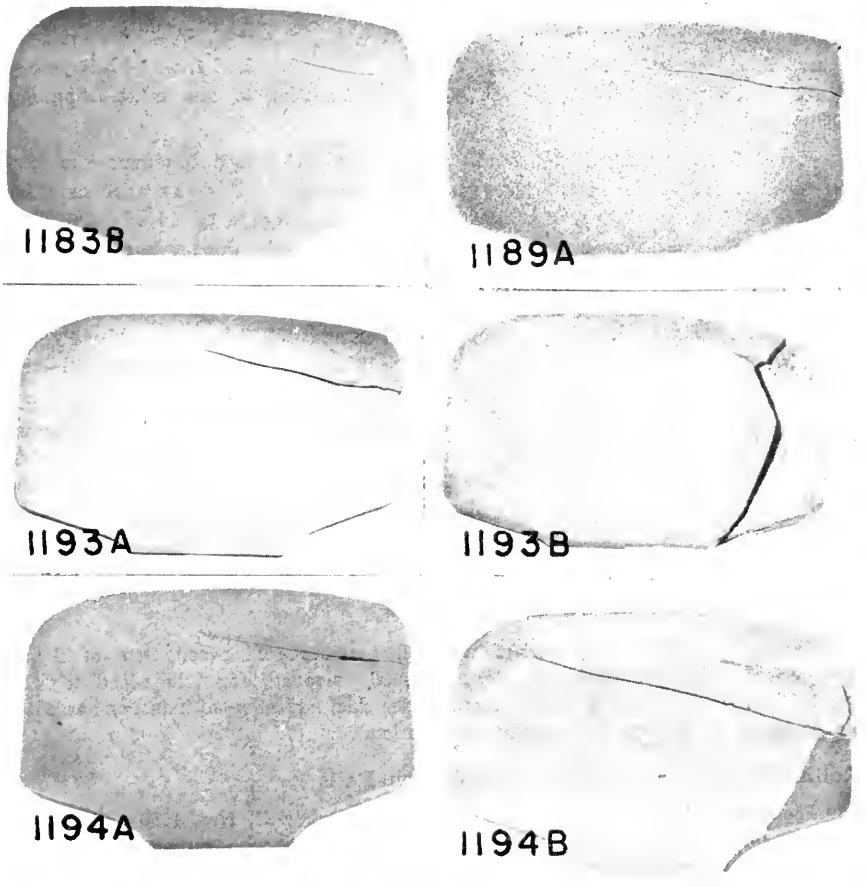


Fig. 1—Shelly Failures Produced in Rolling-Load Tests.

Spec. No.	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000-Lb Wheel Load*
1183B	136-lb chrome-vanadium rail	368	4,509,000
1189A	136-lb high-silicon rail	294	4,991,000
1193A	133-lb 1.63% Si high silicon rail	321	1,562,300
1193B	133-lb 1.63% Si high silicon rail	321	1,077,000
1194A	133-lb 1.63% Si high silicon rail	322	1,083,000
1194B	133-lb 1.63% Si high silicon rail	322	1,280,000

hardened zone on the gage corner is approximately ¾ in and the depth is approximately ⅜ in. The average Brinell hardness is 340. Treatment was obtained by a continuous-moving inductor using 35 kw of 900-cycle power at a lineal rate of 16 in of rail per minute. The company stated that it was arranging for some field trials of this process with several railroads. It was therefore thought advisable to also make laboratory rolling-load tests on these specimens.

Fig. 2 shows specimen No. CRH1 as received and etched in ammonium persulfate to show the hardened gage corner. This specimen and others were used for Rockwell "C" hardness tests. The maximum hardness reading obtained was 370 when converted to Brinell numbers, and the average readings in the hardened zone was between 340 and 350 Brinell numbers. Fig. 2 also shows the shelling cracks developed in five specimens from these induction-hardened rails and Table 1 shows rolling-load tests of six specimens. The average cycle for failure is 730,000, or considerably less than the 1 million cycle average we have established for standard carbon-steel rails.

These rails undoubtedly will wear less on curves than standard carbon-steel rails. In the laboratory rolling-load tests there was no flow of the metal at the gage corner before the shelling crack developed. It is known that there is considerable locked-in stress in these induction-hardened rails. This is indicated by a slight bowing of the rail heads and is more dramatically illustrated when a saw cut is started into the hardened zone. When a shallow notch has been sawed the head suddenly cracks about one-half way across, indicating a locked-in tension stress in the induction-hardened zone. It is thought that in service these stresses would be somewhat relieved by the wheel loads rolling on the gage corners of the rails.

These laboratory tests correlate with all previous rolling-load tests of flame-hardened rails in that these rails do not usually give as long rolling-load tests as standard carbon-steel rails. It would seem that the chief advantage of induction hardening would be to resist gage-corner wear or abrasion.

Rolling-Load Tests of Two High-Silicon Rails

The Colorado Mill furnished two more high-silicon rails, Nos. 1190 and 1191 in Table 1 for rolling-load tests. These were 133-lb section with carbon 0.75 percent; manganese 0.94 percent and silicon 0.65 percent. Their average Brinell hardness was 303 and 304. The four rolling-load tests on these specimens ran from 2,055,000 to 4,678,000 cycles, with an average of 3,349,000 cycles. This average is higher than previous tests of high-silicon rails. All laboratory tests of high-silicon rails have given rolling-load test results which average about twice as high as standard carbon-steel rails. The shelling cracks produced in these four specimens are shown in Fig. 3.

Shelling Produced in Service

Fig. 4a shows a typical 90 percent detail fracture from shelling produced in service in rail No. 978 as listed in the report on Failures in Control-Cooled Rails, Appendix 2–a. The shelling crack has a short vertical section about ½ in from the gage side of the rail head. This probably indicates where the shelling first started. Fig. 4b is the shelling crack opened up by sawing, showing that it extended at least 5 in along the gage corner. A metallographic examination of the steel from this rail near the area where the shelling developed located the large inclusion shown in Fig. 4c at about 65× magnification. It is not often that such large inclusions are found in modern railroad rails.

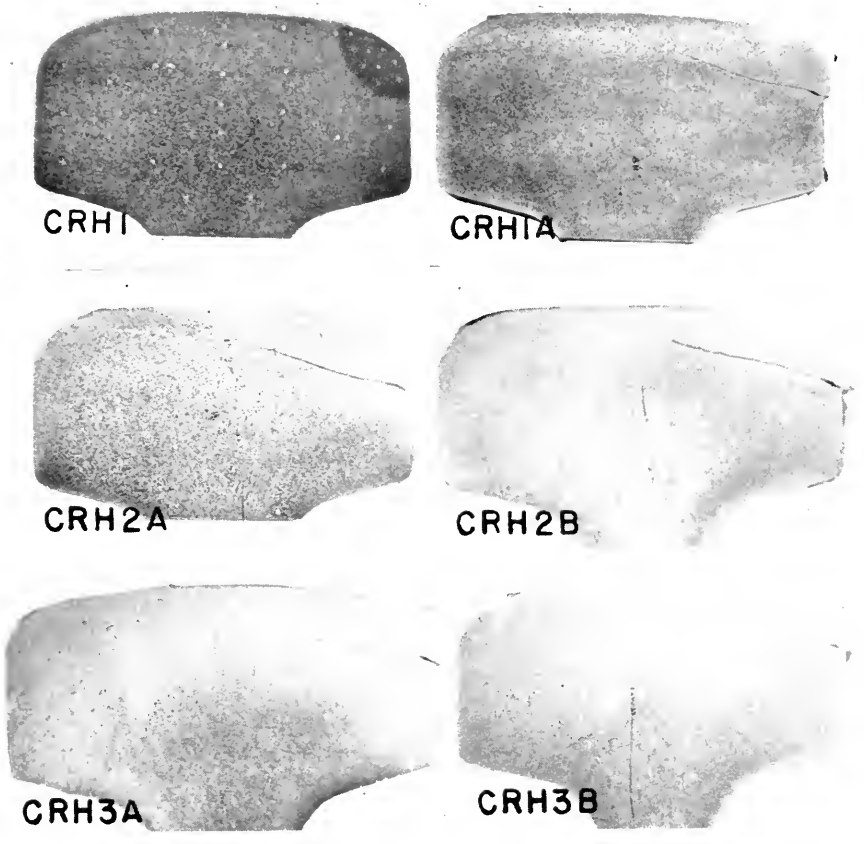


Fig. 2—Specimens of Induction-Hardened Rails.

Specimen No. CRH1 etched to show induction-hardened area. Specimen etched in ammonium persulfate

Spec. No.	*Kind of Specimen*	*Cycles of 50,000 Lb Wheel Load*
CRH1A	132-lb std. rail induction hardened	803,100
CRH2A	132-lb std. rail induction hardened	717,800
CRH2B	132-lb std. rail induction hardened	756,100
CRH3A	132-lb std. rail induction hardened	686,800
CRH3B	132-lb std. rail induction hardened	592,100

Another rail from service was received, laboratory No. 995, which had developed complete fractures through the rail at two detail fractures from shelling which were located only 32 in apart. It was not stated if these two failures had caused a derailment but this is a condition which can easily do so. These two fractures so close together in this rail emphasize the necessity for careful detector car tests of rails for detail fractures.

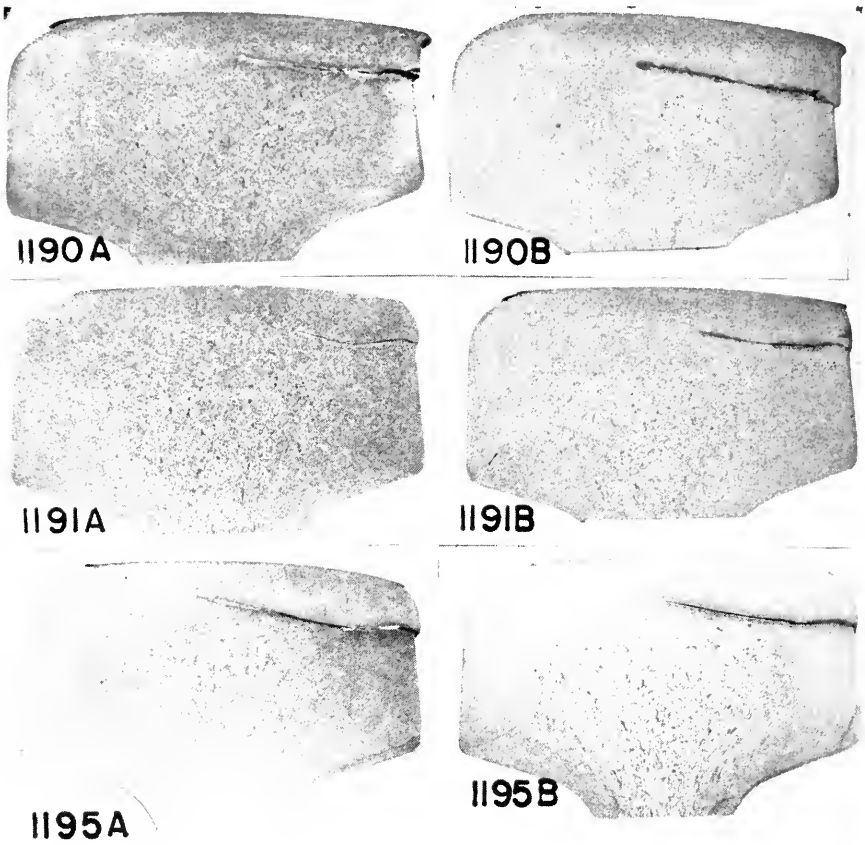


Fig. 3—Shelly Failures Produced in Rolling-Load Tests.

Spec. No.	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000-Lb Wheel Load*
1190A	133-lb 0.65% silicon rail	303	4,678,000
1190B			3,380,000
1191A	133-lb 0.65% silicon rail	304	2,055,000
1191B			3,285,000
1195A	133-lb 0.65% silicon rail	326	606,000
1195B			1,015,000

Rolling-Load Tests to Produce Detail Fractures

Only two detail fractures have been produced in the past year because chromium–vanadium rails are being tested which run a long time. Also, failures have occurred in the cradle and crank shaft of the one rolling machine used to produce detail fractures.

The first chrome–vanadium rail No. 1182 developed a 5 percent detail fracture from a fin pushed out on the gage corner after being rolled 9,258,500 cycles. This is

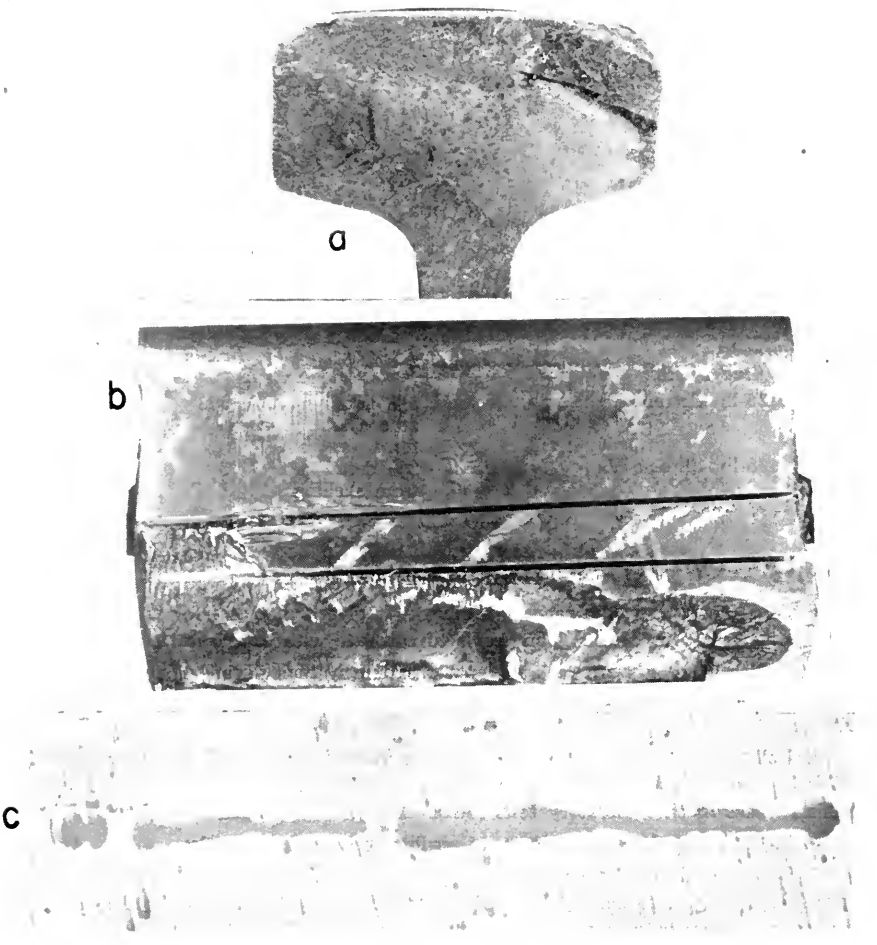


Fig. 4—Shelling Produced in Service, Rail No. 978.

a. 90% detail fracture from shelling.
b. Shelling along gage corner opened up.
c. Photomicrograph of inclusion at 65× magnification.

an extra long test for a chrome–vanadium rail, and even after this much rolling of 50,000-lb wheel load the rail head was not deformed by flow or a shelling crack had not developed, as shown in Fig. 5.

The second specimen of chrome–vanadium rail No. 1183 developed an 8 percent detail fracture from shelling at 2,827,900 cycles, which is a short test for this alloy steel. This again shows the variation obtained in laboratory rolling-load tests of chrome–vanadium rails, but it also emphasizes that some tests of these rails last five or more times as long as standard carbon steel rails.

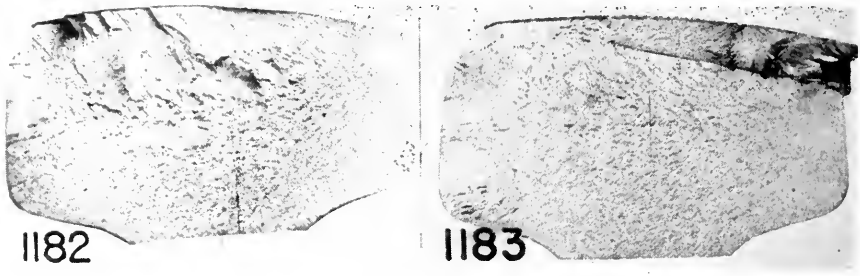


Fig. 5—Specimens Tested to Produce Detail Fractures.

Specimen Number	*Kind of Rail*	*Type of Fracture*	*Average Brinell Hardness*	*Cycles of 50 000 Lb Wheel Load*
1182	136-lb Chrome–Va	5% detail at corner fin.	373	9,258,500
1183	136-lb Chrome–Va	8% detail from shelling	368	2,827,900

Summary

1. Laboratory tests of chrome–vanadium rails give high cycles for failure but with considerable scatter in results. This seems to correlate with experience in service.

2. Rolling-load tests are reported on six extremely high-silicon rails with 1.63 percent silicon. These specimens did not give as good results as previous tests on rails with less than 1 percent silicon content.

3. Rolling-load tests are reported on six induction-hardened rails furnished by Teleweld, Inc. These hard rails resist flow or abrasion on the gage corner but develop shelling cracks in the laboratory tests sooner than standard carbon-steel rails.

4. Pictures are shown in Fig. 4 of shelling produced in service.

5. One rail, laboratory No. 995, was examined which had developed complete fractures in service at two detail fractures from shelling only 32 in apart in the rail. This emphasizes the necessity of careful detector car tests of rails for detail fractures.

6. Two detail fractures from shelling were produced in laboratory rolling-load tests of 136-lb chrome–vanadium rails with Brinell hardness of 368 and 373. These two rails ran 2,837,900 and 9,258,500 cycles. This again shows the variation obtained in laboratory tests of chrome–vanadium rails but it also emphasizes that some tests last five or more times as long as standard carbon-steel rails.

Appendix 8-d

Investigation into the Significance of the Hydrogen Level in Rail Steel

By L. H. Winkler
Retired Metallurgical Engineer, Bethlehem Steel Company

A meeting was held in Chicago on November 20, 1957, with representatives of Subcommittee 8, AREA Committee 4—Rail, and representatives of the rail producer members of the Joint Contact Committee, for the purpose of inquiring into a suggested research project to study the influence of hydrogen on the "shelly" phenomenon.

To provide some basis for the discussion of this project and since there was no available specific information regarding the hydrogen level of currently produced control-cooled rails, the chairman of the Joint Contact Committee arranged to have hydrogen determinations made on random samples of rails taken from current mill production.

The results obtained by Bethlehem research on ½ in diameter specimens taken from the rail head at the gage corner and located with center line at ⅜ in from the side and ⅜ in from the top of the rail head are shown in the following table and were presented at the meeting. The United States Steel Corporation reported at the meeting that its results from similar research were in substantial agreement with those reported here.

Heat No.	*Date Rolled*	*Rail Section*	*Rail Serial*	*Hydrogen, PPM*
Z 89T414	7/11/57	155 PS	A–42	0.3
Y 90T503	9/27/57	140 RE	C–19	0.4
Y 90T352	6/11/57	132 RE	D–4	0.3
Y 89T566	10/ 2/57	115 RE	H–14	0.3

It is to be noted that these results indicate that the hydrogen level in the location where shelling generally takes place is considerably less than 1 ppm.

After a thorough discussion, it was suggested, before embarking on the proposed research project, that rails that have developed shelly spots in service be investigated for hydrogen content of the steel. It was further proposed that the specimens from these rails for hydrogen determination be taken to represent the portion of the rail that had shelled and also the portion of the same rail that had not developed that phenomenon.

Kurt Kannowski of the AAR accepted the responsibility for obtaining representative rail specimens taken from the tracks of several railroads. He forwarded to Bethlehem Steel Company six such specimens from three rails rolled at Lackawanna and removed from the Great Northern Railroad tracks, and six similar specimens from three rails rolled at Steelton and taken out of track of the Norfolk & Western Railroad. Each of these lots of six specimens represented shelled and shell-free portions of the same rail.

Mr. Kannowski sent similar specimen sets to the United States Steel Corporation of rails produced at Gary and removed from service on the Great Northern.

The results of hydrogen determinations made by the research departments of the United States Steel Corportion and of Bethlehem Steel Company are shown in the following tabulation. The samples analyzed by Bethlehem were located ⅜ in from the side of the head and ⅜ in from the top of the head at the gage corner. The

samples analyzed by United States Steel Corporation were obtained from the head cross section near the gage corner at a position where the quarter point of the head width intersects mid-thickness of the head.

It is to be noted that all of these tests failed to show hydrogen contents in any significant amounts and, furthermore, the results obtained from specimens of current production as well as from rails that have shelled in service indicate no evidence that hydrogen contributes to shelling.

Lackawanna Rails From Great Northern Track

Sample Number	*H_2 in PPM (Duplicate Determinations) Gage Corner*	*Center*	*Rail Section and Date Rolled*
1 Shelled	0.6–0.5	0.6–0.5	112 RE July 1940
1 Clear	0.4–0.5	0.3–0.4	
2 Shelled	0.3–0.4	0.3–0.4	112 RE July 1939
2 Clear	0.4–0.5	0.3–0.3	
3 Shelled	0.4–0.5	0.7–0.7	112 RE July 1941
3 Clear	0.4–0.5	0.6–0.6	
Average	0.45	0.47	

Steelton Rails From Norfolk & Western Track

Sample Number	*H_2 in PPM (Duplicate Determinations) Gage Corner*	*Center*	*Rail Section and Date Rolled*
1 Shelled	0.6–0.5	0.5–0.6	132 RE May 1952
1 Clear	0.5–0.6	0.5–0.6	
2 Shelled	0.3–0.3	0.4–0.5	131 RE Nov. 1940
2 Clear	0.3–0.3	0.4–0.4	
3 Shelled	0.6–0.4	0.6–0.4	132 RE Aug. 1949
3 Clear	0.6–0.5	0.5–0.4	
Average	0.46	0.48	

Gary Rails From Great Northern Track

Sample Number	*H_2 in PPM*	*Rail Section and Date Rolled*
1 Shelled	0.30	112 RE March 1947
1 Clear	0.63	
2 Shelled	0.14	112 RE March 1947
2 Clear	0.14	
3 Shelled	0.15	112 RE March 1947
3 Clear	0.16	

Appendix 8-e

Final Report on a Three-Dimensional Photoelastic Investigation of the Stress Distribution in the Head of a Model of a Railroad Rail Along Lines Parallel to the Axis of the Rail

By M. M. Frocht

Research Professor of Mechanics; Director of Experimental Stress Analysis, Illinois Institute of Technology

Introduction

This report may be viewed as an extension or supplement to the report (1)* of June 26, 1953, on a "Three-Dimensional Investigation of the Principal Stresses and Maximum Shear in the Head of a Railroad Rail." The above report was confined to stress determinations along lines in the plane of symmetry of the rail, which is transverse to the axis of the rail and passes through the center of the wheel. In the present report we deal with the stresses in the rail in the region of contact along interior lines parallel to the axis of the rail, such as line F–F, Fig. 1. The study was undertaken in order to see whether the interior stresses along the length of the rail may not throw some light on the possible cause of shelly failures.

The photoelastic models and loading jigs were of the same material and dimensions as those described in the first report. The general method of procedure was also the same. Specifically, the rectangular stress components were determined by the shear-difference method (2), (3), (4) from sub-slices containing frozen stresses. Typical stress patterns of a transverse and longitudinal slice, from which the sub-slices were taken, are shown in Figs. 2 and 3.

The stresses were determined in two different models under two different loads. In one model the load was 51 lb, which is the same as that used in the first study. The results from this model showed that while in the vicinity of the load the normal stress components σ_x, σ_y, and σ_z were all compressive, they changed into tensions at points approximately 1 in to either side of the wheel center.

In order to bring out more accurately this state of triaxial tension the tests were repeated with another model and a vertical load of 78.4 lb, which is roughly 50 percent greater than the first load.

It was found that the stress distribution is essentially the same for the higher and lower loads, thus showing that the stress distribution on the lines studied is little affected by the substantial increase in the contact area produced by the larger load.

Lines Studied

(a) Vertical Load 51 Lb—In the first model carrying 51 lb the stresses were determined along the two lines parellel to the axis of the rail passing through points F, G, in the plane of symmetry, Fig. 4. In this determination the initial values of σ_x were taken from the stress curves for lines AO′ and BO′ in the plane of symmetry, which were available from the first report for the same load. The line BO′ passes through the region of the maximum shear close to the region of contact. (See Figs. 12 and 13 in the first report).

(b) Vertical Load 78.4 Lb—The stresses were first determined along lines AO′ and BO′ in the plane of symmetry. Using the initial values from the curves for AO′

* Numbers in parenthesis pertain to references listed at the end of the report.

and BO' the stresses σ_x were next determined along the longitudinal lines F–F, G–G, and H–H passing through the points F, G, and H, Fig. 4. Lines F–F, and G–G were the same as those used for the smaller load.

RESULTS

(a) Vertical Load 51 Lb

Line F–F—Fig. 5 shows the six rectangular stress components along the longitudinal line F–F. It is seen that the normal stresses σ_x, σ_y and σ_z are all compressive in the region near the load and that their maximum numerical values occur under the center of the wheel. Also, as would be expected, σ_y is the greatest of these stresses. The curves further show that all three normal stresses change into tension at $X/L = 0.4$, approximately. Inspection of Fig. 5 further shows that τ_{xy} reaches a maximum at $X/L = 0.27$, where it attains a value approximately equal to 35 percent of the maximum σ_y. The shear component τ_{yz} remains fairly constant in the interval $X/L = 0$ to $X/L = 0.24$. In this interval the magnitude of τ_{yz} is about 20 percent of the maximum σ_y. The shear τ_{xz} was found to be extremely small.

Line G–G—The stresses along line G–G, Fig. 6, shows a similar distribution to that found on line F–F. The magnitudes of the normal stresses, however, were found to be higher than those on line F–F. For example, the stress σ_y at the center of the wheel is about 50 percent greater. The normal stresses along G–G, like those along line F–F, also change from compression to tension as the distance from the wheel center increases. The magnitude and position of the maximum τ_{xy} remain essentially the same as on line F–F. The shearing stress τ_{yz} near the region of contact was found slightly higher on line G–G than that on line F–F.

From the rectangular stress components the principal stresses σ_1, σ_2, and σ_3 were calculated (see Appendix A). These stresses are shown in Fig. 7. As in the case of the normal stresses the principal stresses also change from compression into tension.

(b) Vertical Load 78.4 Lb

Line AO'—The curves in Fig. 8 represent the stress distribution along line AO' in the plane of symmetry. Because of symmetry the shearing stresses τ_{xy}, and τ_{xz} are identically zero.

The stresses σ_x are tensile in the lower half of the head and compressive in the upper half. Except for a small region at point A the stresses σ_y are compressive all along the line AO'. The stresses σ_z have a small tensile value at the lower fiber, a small compressive value at the top and are practically zero in the middle of the line AO'. The vertical shearing stresses τ_{zy} are small and remain fairly constant across this line. In general, these stress distributions are similar to those produced by the smaller load.

Line BO'—The curves in Fig. 9 show the stresses along line BO'. As already mentioned, this line was chosen to pass through the point of maximum shear which occurs close to the contact surface. The stresses σ_x, σ_y, and σ_z are similar in shape to those for line AO', but the numerical values in the contact region are much higher on line BO'. For example, at contact σ_y equals — 44 psi approximately on line BO' and only — 25 psi on line AO'. Similarly, σ_x is — 38 psi on BO' and only — 20 psi approximately on line AO'. The stresses σ_z at the lower fiber of the head becomes compressive, whereas on AO' it was tensile.

Line F–F—The curves in Fig. 10 show the rectangular stress components along the longitudinal line F–F, Figs. 1 and 4. These curves are very much similar in shape to those on the same line for the smaller load, Fig. 5, except for τ_{xz}, which is no longer small. The stress σ_x in Fig. 10 obtained from numerical integration vanishes at the free end where $X/L = 1$, and thus satisfies the boundary condition. As in the case of the smaller load, the state of stress changes from large triaxial compression into small triaxial tension as the distance from the wheel center increases. The greatest of the three shearing stresses is τ_{xy}, which reaches a maximum value of 50 percent of the maximum σ_y at $X/L = 0.3$.

Fig. 11 shows the principal stresses σ_1, σ_2, and σ_3. The normal stress components σ_x, σ_y, and σ_z were also plotted for purpose of comparison. As would be expected, these components lie between the maximum and minimum principal stresses σ_1, and σ_3.

It will be noted that at point M, where $X/L = 0.35$, approximately, the principal stress σ_1 assumes a value almost equal to 50 percent of the maximum σ_y. Inspection of the curves further shows that the maximum compression, σ_3, does not occur at wheel center, but at $X/L = 0.2$ approximately.

The principal stress directions were also calculated (see Appendix B). The direction of each principal stress is given by the three angles θ_x, θ_y, and θ_z which the stress makes with the X, Y, and Z axes, respectively. The following table gives the principal stress directions at point M, where the maximum tension occurs:

	θ_x	θ_y	θ_z
σ_1	55.2°	54°	55°
σ_2	102.1°	124.7°	37.4°
σ_3	98.1°	54.9°	78.4°

The plane at point M, Fig. 11, on which the maximum σ_1 acts will be called the P-plane and the normal stress on planes parallel to plane P will be denoted by σ_p. The values of σ_p at $X/L = 0$ and $X/L = -0.35$ were also calculated (see Appendix C), and are given in the table below:

X/L	σ_p
0.35	11 psi
0	— 13 psi
— 0.35	— 10 psi

Line G–G—The stress distribution along line G–G is shown in Fig. 12. The curves for the rectangular stress components have characteristics similar to those observed along line F–F. The numerical values of the stresses in the loaded region are higher. The maximum compression σ_y at the wheel center is about 70 percent greater than that on line F–F. The normal stresses also change from large triaxial compression to small triaxial tension. The maximum τ_{xy} takes place at point N where $X/L = 0.3$ and is slightly lower than that on line F–F. The principal stresses are shown in Fig. 13. The results are also similar to those for line F–F. Of particular importance is point M at $X/L = 0.38$, where the maximum σ_1 occurs. The numerical value of maximum σ_1 is about the same as that on line F–F. The directions of the principal stresses at point M were again evaluated and are given in the table below:

	θ_x	θ_y	θ_z
σ_1	64.4°	70.8°	32.9°
σ_2	101.1°	151.2°	63.8°
σ_3	151.7°	69.2°	71.7°

The normal stresses σ_p at $X/L = 0$ and -0.38 were also determined, and their values at these positions are shown in the table below:

X/L	σ_p
0.38	12 psi
0	— 14.8 psi
— 0.38	1.6 psi

Line H–H—Fig. 14 shows the rectangular stress components on line H–H. The curves are similar to those along line F–F, and G–G. The maximum τ_{xy} at N is slightly higher than that on line G–G, but the position of N remains essentially the same. Small triaxial tensions were also found. The principal stresses, σ_1, σ_2, σ_3 are shown in Fig. 15. The maximum σ_1 at M where $X/L = 0.36$ is about 36 percent smaller than the maximum value on line G–G. The principal stress directions at M are tabulated below:

	θ_x	θ_y	θ_z
σ_1	61.6°	58.5°	44.9°
σ_2	118.6°	124.4°	47.8°
σ_3	44.1°	134.1°	88.5°

The values of the normal stresses σ_p at three significant positions are shown in the table below:

X/L	σ_p
0.36	7.7 psi
0	— 10.8 psi
— 0.36	— 7.3 psi

Checks—The results were checked in two ways. The first check is provided by the fact that the integrated value of σ_x along the longitudinal lines F–F, G–G, and H–H satisfy the boundary conditions, i.e., σ_x vanishes at the free end, where $X/L = 1$.

The second check is provided by the fact that the values of σ_y and σ_z determined from the longitudinal sub-slices containing lines F–F, G–G, and H–H agree with the values of σ_y and σ_z determined from the sub-slices in the transverse section of symmetry.

Table 1 gives the stresses in pounds per square inch for the steel rail for a load of 30,000 lb. These were calculated from the stresses in the model by means of the same transition formulas as those used in the first report. (Eq's (1), (2), Appendix D).

Chief Sources of Error—The photoelastic models were carefully prepared and the loads were accurately measured. The photoelastic data, i.e., the birefringence and isoclinic parameters, were determined by precision methods and the calculations carefully checked. The only major source of error in the photoelastic work would come from the rather large area of contact, which in all probability modifies somewhat the true distribution of the contact pressures in the rail. However, the results from the two different loads show essentially the same characteristics so that no serious errors have been introduced by the higher load.

It would appear that the more concentrated contact pressure in the steel rail would tend to produce a more severe state of stress than that in the photoelastic model. The main source of error probably lies in the transition formulas.

TABLE 1

Rail Load—30,000 lb Model Load—78.4 lb

	Line F-F	*Line G-G*	*Line H-H*
Position of line below contact	0.05 in	0.04 in	0.11–0.2 in
Range of σ_x	12,000 psi to −45,000 psi	18,000 psi to −96,000 psi	7,500 psi to −52,000 psi
Range of σ_y	9,000 psi to −75,000 psi	6,000 psi to −126,000 psi	6,000 psi to −110,000 psi
Range of σ_z	9,000 psi to −13,500 psi	24,000 psi to −36,000 psi	9,000 psi to −10,800 psi
Range of τ_{xy}	±35,000 psi	±30,000 psi	±37,500 psi
Range of σ_p	33,000 psi to −39,000 psi	36,000 psi to −44,000 psi	23,400 psi to −32,400 psi
Range of τ_{max} from zero to	42,000 psi	51,000 psi	54,000 psi

DISCUSSION AND CONCLUSIONS

The complete state of interior principal stresses along critical lines parallel to the axis of the rail have been determined photoelastically in the head of a model of a railroad rail.

From the nature of the moving load it is apparent that each point in the rail is subjected to a fluctuating state of stress. The stress distributions which we have obtained from static conditions represent the stress history at a point on the lines studied as a function of the instaneous position of the wheel relative to the point. The curves of the stress distributions are, in effect, influence curves for the stresses for a moving load.

The study revealed several dangerous states of stress, which in themselves or in combination may contribute to, or produce, the shelly failure:

(1) The results show that the normal stress components σ_x, σ_y, and σ_z alternate between large compressions and relatively small tensions. The tensile triaxiality, which was rather unexpected, is known to produce embrittlement and may be a significant factor in failure.

(2) There exist oblique planes, the P-planes, which are subjected to completely reversed large normal stresses. The range of these stresses exceeds the endurance limit of 33,000 psi for completely reversed normal stresses (6) on lines F–F and G–G, and comes close to it in the region H–H of shelly failure.

(3) The range of the alternating shears τ_{xy} is $\pm$ 35,000 psi approximately, and the endurance limit for completely reversed shear is 37,000 psi (7).

(4) The planes on which the maximum shears during each loading cycle act, which we shall denote as Q-planes, are subjected to fluctuating shears and normal stresses. The range on line H–H of the variable shear on these planes is at least from 0 to 54,000 psi, which comes dangerously close to the endurance limit of 59,000 psi (5). A possibility exists that these shears may also reverse direction, which would certainly aggravate matters.

No definite conclusions regarding the possible cause of failure can be drawn, largely because no factual information is available on the behavior of materials under such complicated states of stress as encountered in this problem.

The most likely cause of failure lies either in the fluctuating shears on the Q-planes or in the reversal of the shears τ_{xy} which are approximately equal to their respective endurance limits. The decisive factor may, perhaps, lie in the effects of the associated stresses.

Whether the maximum shear in the region H–H produces yielding is uncertain because of the severe strain hardening, and also because the transient nature of the high stress may not allow sufficient time to develop yielding.

If failure is due to either one of these causes, and the transition formulas are approximately correct, then a wheel load of 30,000 lb would seem sufficient to put the rail in a state of incipient failure. A larger load would be required to produce failure by alternating normal stresses.

The reason why fractures do not occur in the regions F–F and G–G probably lies in the complicated effects which the combination of strain hardening, fatigue, and residual stresses may have on the strength of steel. It is known that fatigue may under certain conditions actually increase the strength of a metal before it weakens it (8).

Fatigue tests on actual rails may throw light on the cause of failure. Failure due to τ_{max} is likely to produce a jagged surface, more or less horizontal, whereas failure due to τ_{xy} is likely to produce a relatively even surface.

APPENDIX A—MAGNITUDE OF THE PRINCIPAL STRESSES

Given the six rectangular stress components at a point, the values of the three principal stresses can be determined from the cubic equation (9):

$$\sigma^3 - I_1\sigma^2 + I_2\sigma - I_3 = 0 \quad \ldots\ldots (1)$$

where I_1, I_2, and I_3 are the stress invariants at the point

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$
$$I_2 = \sigma_x\sigma_y + \sigma_y\sigma_z + \sigma_x\sigma_z - \tau_{xy}^2 - \tau_{yz}^2 - \tau_{xz}^2$$
$$I_3 = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{yz}\tau_{xz} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{xz}^2 - \sigma_z\tau_{xy}^2$$

The roots of the cubic equation are found by Cardan's method (10). This method yields directly the three roots without applying a trial-and-error procedure. By letting $\sigma = y + \frac{I_1}{3}$ the above equation is transformed into the following form:

$$y^3 + ay + b = 0 \quad \ldots\ldots (2)$$

where the constants a and b are given by

$$a = I_2 - I_1^2/3$$
$$b = -I_3 + I_1I_2/3 - 2I_1^3/27$$

The three roots of Eq. (2) are

$$y_1 = 2\sqrt{\frac{-a}{3}}\cos\frac{\phi}{3};\ y_2 = -2\sqrt{\frac{-a}{3}}\cos\left(60 - \frac{\phi}{3}\right);$$

$$y_3 = -2\sqrt{\frac{-a}{3}}\cos\left(60 + \frac{\phi}{3}\right)$$

where,

$$\cos\phi = 27\ b/2a\ \sqrt{-a}$$

The three principal stresses are then given by

$\sigma_1 = y_1 + I_1/3$
$\sigma_2 = y_2 + I_1/3$
$\sigma_3 = y_3 + I_1/3$

APPENDIX B—DIRECTIONS OF THE PRINCIPAL STRESSES

Let n_x, n_y, and n_z be the direction cosines of a principal plane, and σ the magnitude of the principal stress acting on this plane. It is shown in the theory of elasticity (9) that the following relations must be satisfied:

$$(\sigma_x - \sigma) n_x + \tau_{xy} n_y + \tau_{xz} n_z = 0 \quad \ldots\ldots (1)$$
$$\tau_{yx} n_x + (\sigma_y - \sigma) n_y + \tau_{zy} n_z = 0 \quad \ldots\ldots (2)$$
$$\tau_{zx} n_x + \tau_{zy} n_y + (\sigma_z - \sigma) n_z = 0 \quad \ldots\ldots (3)$$

In addition, the direction cosines have to meet the condition

$$n^2_x + n^2_y + n^2_z = 1 \quad \ldots\ldots (4)$$

The above equations can be solved for n_x, n_y, and n_z. The results are

$$n_z = \frac{1}{\sqrt{1 + \alpha^2 + \beta^2}} \quad \ldots\ldots (5)$$
$$n_y = \alpha n_z \quad \ldots\ldots (6)$$
$$n_x = \beta n_z \quad \ldots\ldots (7)$$

where,

$$\alpha = \frac{\tau_{yx}(\sigma_z - \sigma) - \tau_{zx}\tau_{yz}}{\tau_{zx}(\sigma_y - \sigma) - \tau_{yx}\tau_{zy}}$$
$$\beta = -\frac{\alpha\tau_{xy} + (\sigma_z - \sigma)}{\tau_{zx}}$$

APPENDIX C—DETERMINATION OF NORMAL STRESS ON ANY ARBITRARY PLANE

Given the state of stress at a point, the normal stress acting on any arbitrary plane can be determined from the equation (9):

$$\sigma_n = n^2_x \sigma_x + n^2_y \sigma_y + n^2_z \sigma_z + 2n_x n_y \tau_{xy} + 2n_x n_z \tau_{xz} + 2n_y n_z \tau_{yz}$$

where n_x, n_y, and n_z are the direction cosiness of σ_n, or of the normal to the plane.

APPENDIX D—TRANSITION FORMULAS

The transition formulas are taken from the supplementary report of October 1953 (1):

$$(\sigma_x, \sigma_y, \sigma_z, \tau_{max})_p = (\sigma_x, \sigma_y, \sigma_z, \tau_{max})_m \sqrt[3]{\left(\frac{1}{\lambda_p}\right)\left(\frac{\lambda_L}{\lambda_E}\right)^2\left(\frac{1 - \lambda^2 \mu \mu_p^2}{1 - \mu_p^2}\right)^2} \quad \ldots\ldots (1)$$

$$(Z)_p = (Z)_m \sqrt[3]{\frac{\lambda_E}{\lambda_L \lambda_p}\left(\frac{1 - \mu_p^2}{1 - \lambda^2 \mu \mu_p^2}\right)} \quad \ldots\ldots (2)$$

where $(Z)_p$ and $(Z)_m$ are distances from the contact area to points at which the stresses are related by Eq. (1).

Although the above equations are valid only along the load line in the immediate region of contact, they are also used to translate maximum τ_{xy}, maximum σ_p, triaxial tensions, and their corresponding positions in the region not directly under the load.

The essential data for the transition from the Fosterite model to a steel prototype rail are tabulated below:

Notation

P = load between wheel and rail
E = modulus of elasticity
μ = Poisson's ratio
L = characteristic length

Subscripts m and p refer to the model and prototype, respectively.

Fosterite Model	*Steel Prototype*
$L_m = 2/3$	$L_p = 1$
$P_m = 78.4$ lb.	$P_p = 30{,}000$ lb.
$E_m = 2010$ psi	$E_p = 30 \times 10^6$ psi
$\mu_m = 1/2$	$\mu_p = 1/3$

Scale Factors

$\lambda_L = L_m/L_p = 2/3$
$\lambda_p = P_m/P_p = 78.4/30{,}000 = 2.61 \times 10^{-3}$
$\lambda_E = E_m/E_p = 2010/30 \times 10^6 = 6.7 \times 10^{-5}$
$\lambda_\mu = \mu_m/\mu_p = 3/2$

Substituting these values into Eqs. (1) and (2) respectively, we obtain:

$$(\sigma_x, \sigma_y, \sigma_z, \tau_{max})_p = (\sigma_x, \sigma_y, \sigma_z, \tau_{max})_m \sqrt[3]{\left(\frac{10^3}{2.61}\right)\left(\frac{2 \times 10^5}{3 \times 6.70}\right)^2 \left[\frac{1 - \left(\frac{B}{2} \times \frac{1}{3}\right)^2}{1 - \left(\frac{1}{3}\right)^2}\right]^2}$$

$$= 3000\ (\sigma_x, \sigma_y, \sigma_z, \tau_{max})_m$$

$$(Z)_p = (Z)_m \sqrt[3]{\frac{6.7 \times 10^{-5}}{\left(\frac{2}{3}\right)(2.61 \times 10^{-3})} \times \frac{1 - \left(\frac{1}{3}\right)^2}{1 - \left(\frac{3}{2} \times \frac{1}{3}\right)^2}}$$

$$= 0.36\ (Z)_m$$

As already mentioned above, and in the supplementary report of October 1953, these equations would at best be valid in a small region near the contact surface. For points below the surface the transition factors become a function of distance from the contact surface; the stress factor decreasing and the position factor increasing. For example, for a 30,000-lb load on the steel rail and 78.4 lb on the model the transition factor for stress varies from 3,000 at the contact surface to 170 approximately at points A and B in Fig. 4, where the contact effects disappear. The value of 170 was arrived at from the consideration that in geometrically similar bodies, neglecting the effect of Poisson's ratio, the stresses are directly proportional to the load and inversely proportional to the square of the scale ratio. Similarly near the surface of contact the transition factor for position calculated from Eq. (2) is 0.36. At the lower free surface of the head, points A and B in Fig. 4, where the contact effects disappear, the factor becomes 1.5, which is the scale ratio of prototype to model. A consideration of these possible variations shows that the transition factor for line H–H drops to 2900 or 2800, thereby reducing the stresses by about 7 percent. It would also appear that the

weaknesses in the transition formulas are likely to produce greater errors in the triaxial tensions than in the triaxial compressions, because the compression regions are closer to the contact surface than the tensile regions. Specifically, the error tends to yield higher tensile values. The effect of variation of the position factor would be to lower the position of line H–H from 0.11 in to nearly 0.2 in below the contact surface, thus bringing the line H–H closer to the region of the shelly failures.

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(1) Frocht, M. M., "Final Report on a Three-Dimensional Photoelastic Investigation of the Principal Stresses and Maximum Shears in the Head of a Model of a Railroad Rail", and Supplementary Report on "A Three-Dimensional Photoelastic Investigation of the Principal Stresses and Maximum Shears in the Head of a Model of a Railroad Rail", AREA Proceedings, Vol. 55, page 854.

(2) Frocht, M. M. and Guernsey, R. Jr., "Studies in Three-Dimensional Photoelasticity —The Application of the Shear Difference Method to the General Space Problem", Proceedings, 1st U. S. Nat. Congr. Appl. Mech., December 1952.

(3) Frocht, M. M. and Guernsey, R. Jr., "Further Work on the General Three-Dimensional Photoelastic Problem", Journal Applied Mechanics, Volume 22, No. 2, June 1955.

(4) Frocht, M. M., Pih, H., and Landsberg, D., "The Use of Photometric Devices in the Solution of the General Three-Dimensional Photoelastic Problem", Proceedings, Society Experimental Stress Analysis, Volume XII, No. 1, 1954.

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(6) AREA Proceedings, Vol. 51.

(7) AREA Proceedings, Vol. 58, page 971.

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(9) Timoshenko, S., Goddier, J. N., "Theory of Elasticity", McGraw–Hill, New York, 1951.

(10) Uspensky, J. V., "Theory of Equations", McGraw–Hill, New York, 1948.

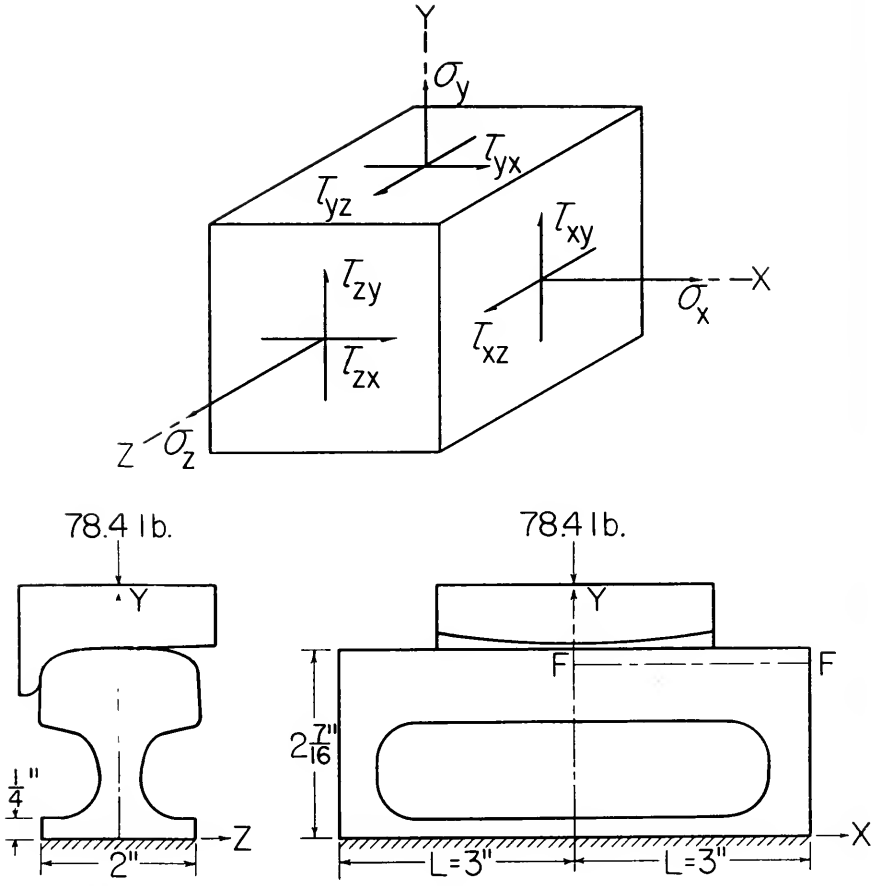

Fig. 1—Notation and model.

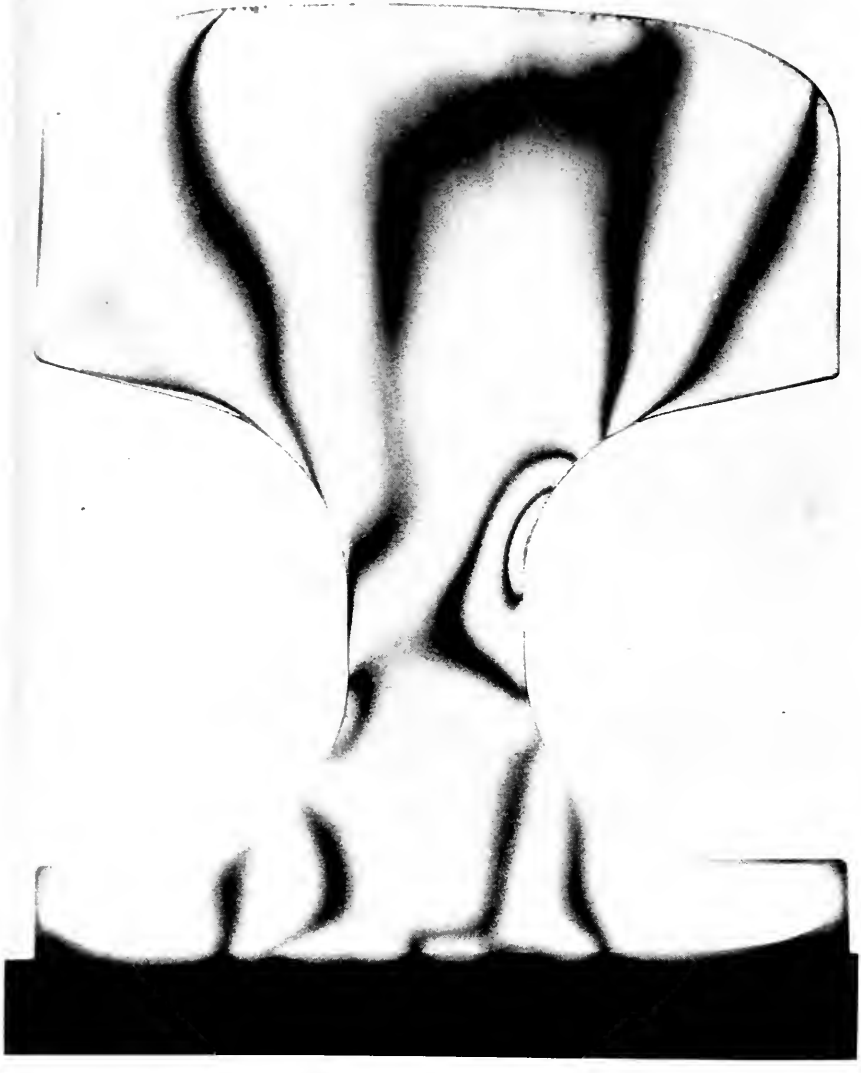

Fig. 2—Stress pattern of the transverse section of symmetry. Fosterite model. Vertical load 78.4 lb.

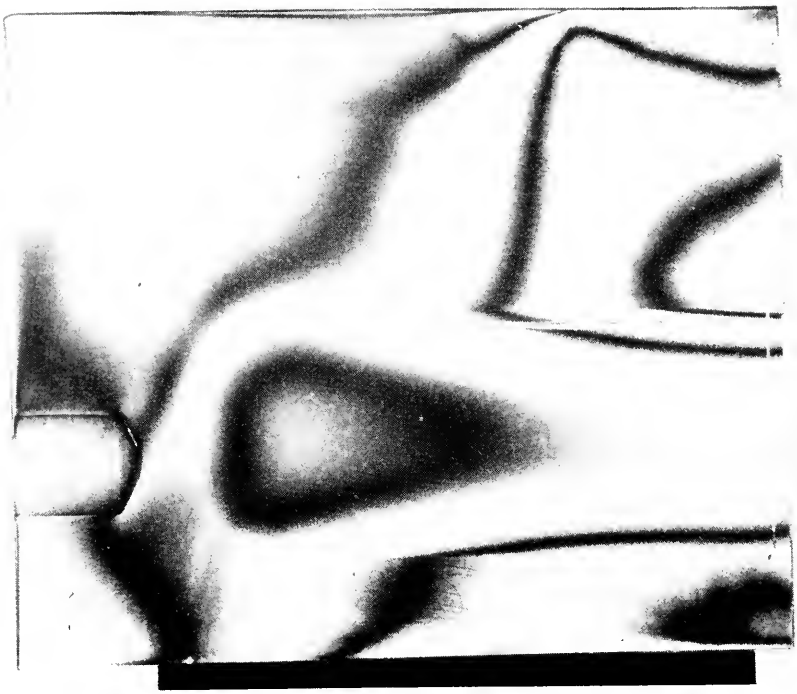

Fig. 3—Stress pattern of a longitudinal slice. Fosterite model. Vertical load 78.4 lb.

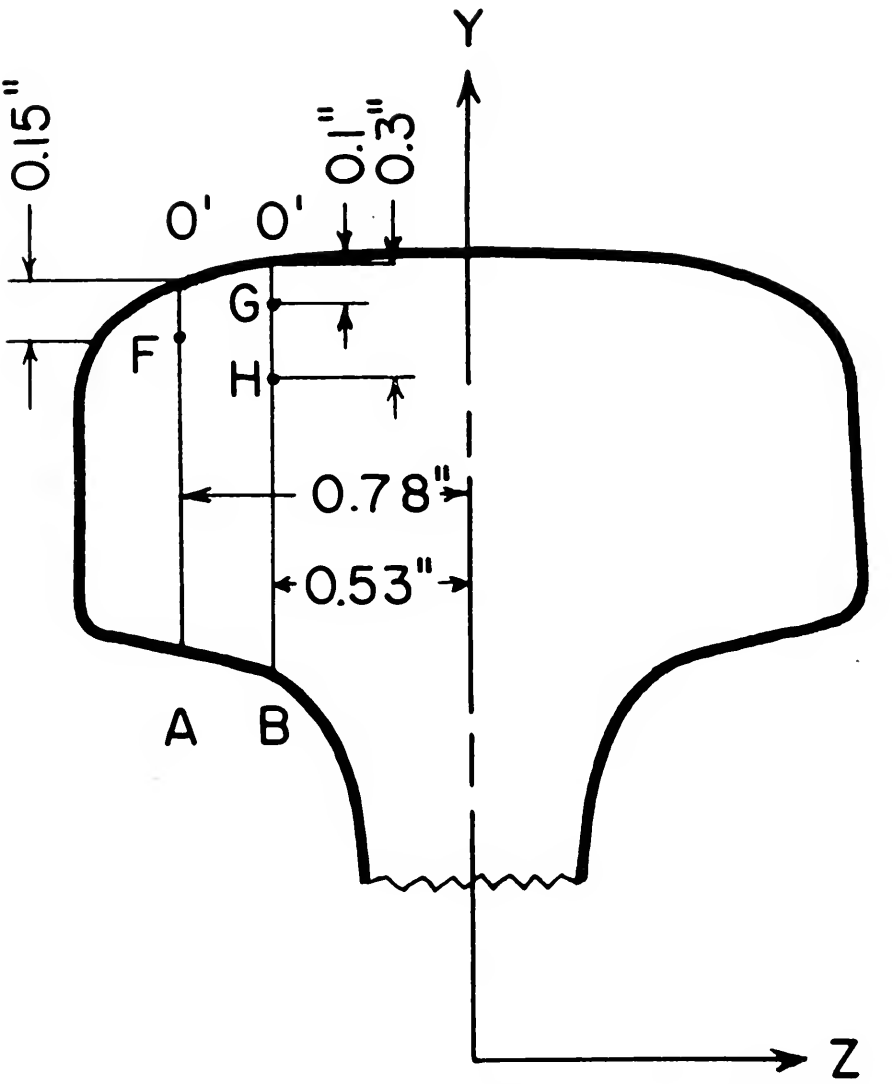

Fig. 4—Sketch showing locations of lines AO', BO', and of longitudinal sub-slices through F, G, and H.

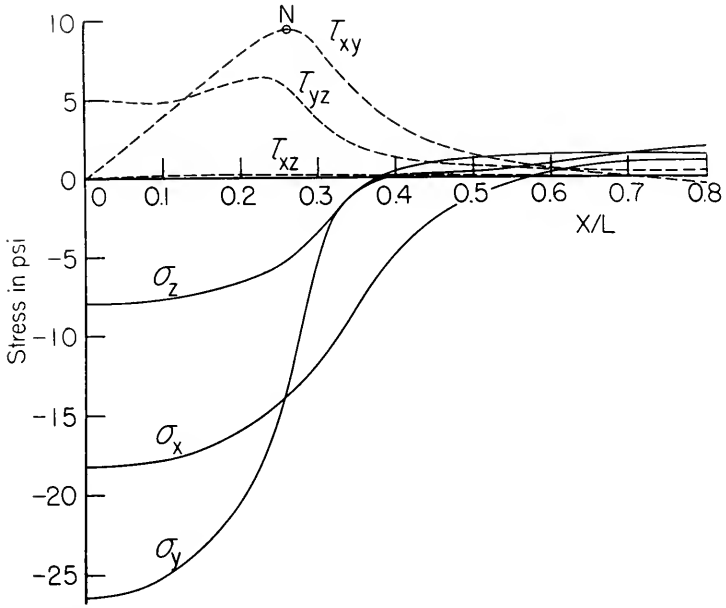

Fig. 5—Rectangular stress components for line F–F. Vertical load 51 lb.

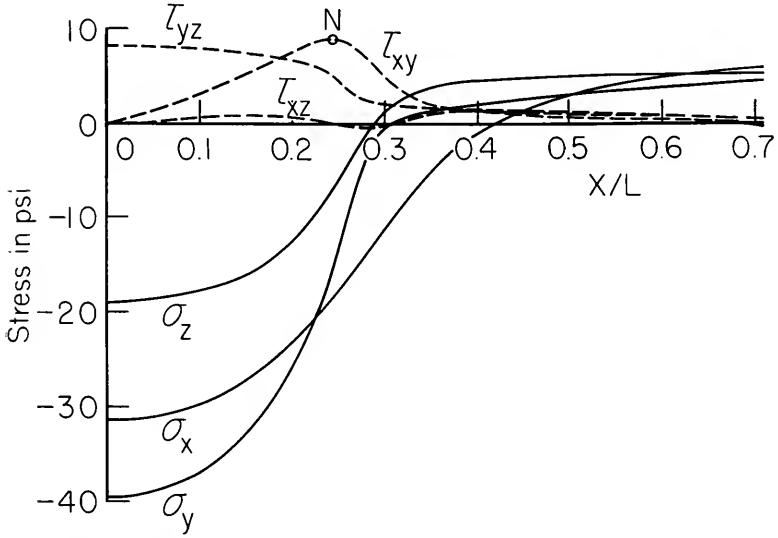

Fig. 6—Rectangular stress components for line G–G. Vertical load 51 lb.

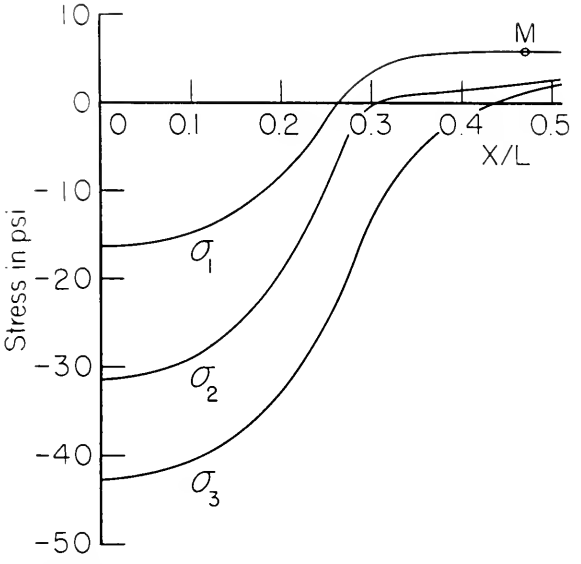

Fig. 7—Principal stresses for line G-G. Vertical load 51 lb.

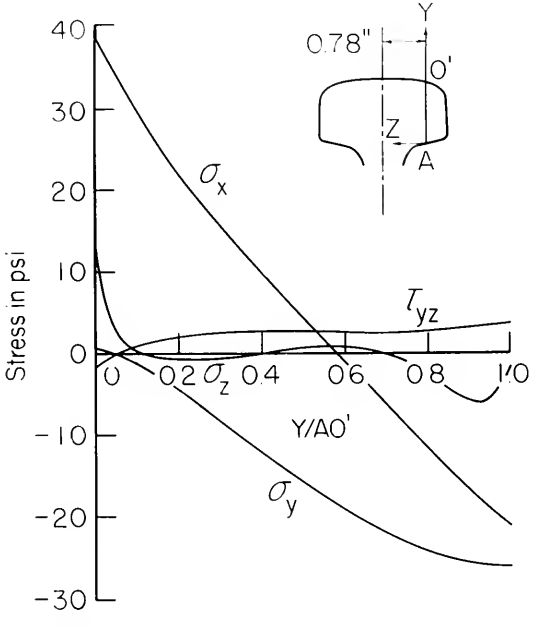

Fig. 8—Rectangular stress components for line AO′ in the phane symmetry. Vertical load 78.4 lb.

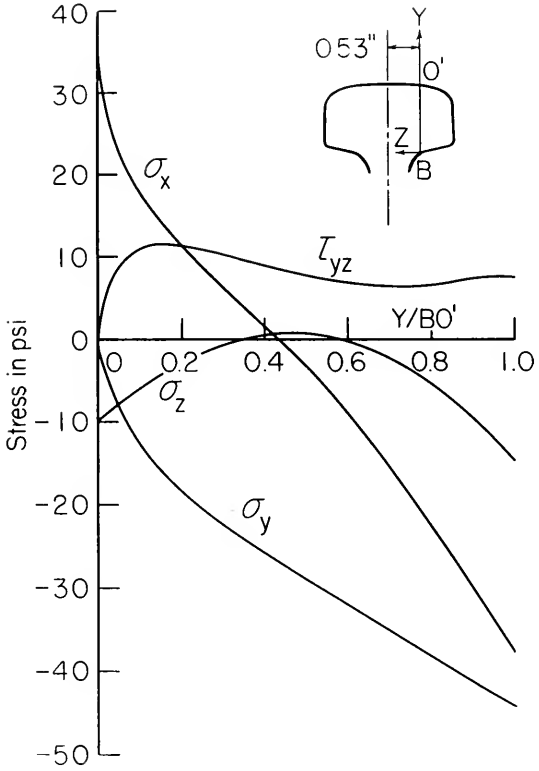

Fig. 9—Rectangular stress components for line BO′ in the plane of symmetry. Vertical load 78.4 lb.

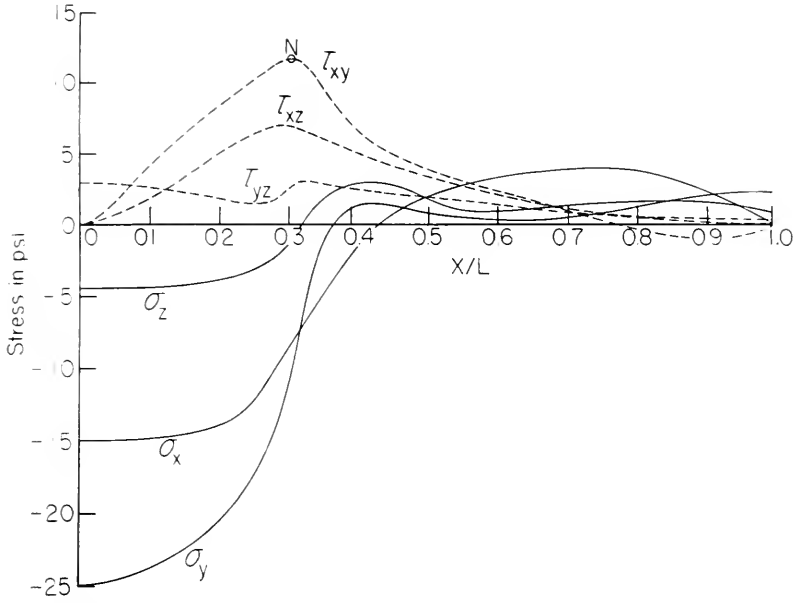

Fig. 10—Rectangular stress components for line F–F. Vertical load 78.4 lb.

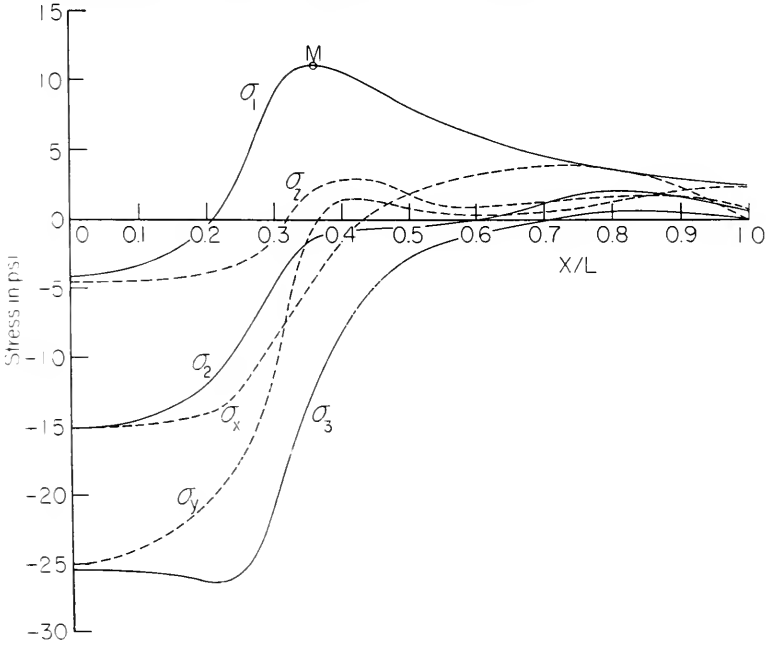

Fig. 11—Comparison of principal stresses with rectangular stress components on line F–F. Vertical load 78.4 lb.

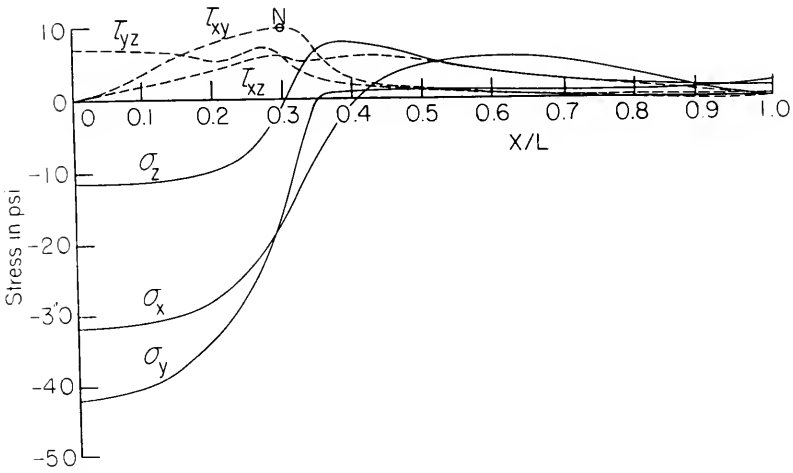

Fig. 12—Rectangular stress components for line G–G. Vertical load 78.4 lb.

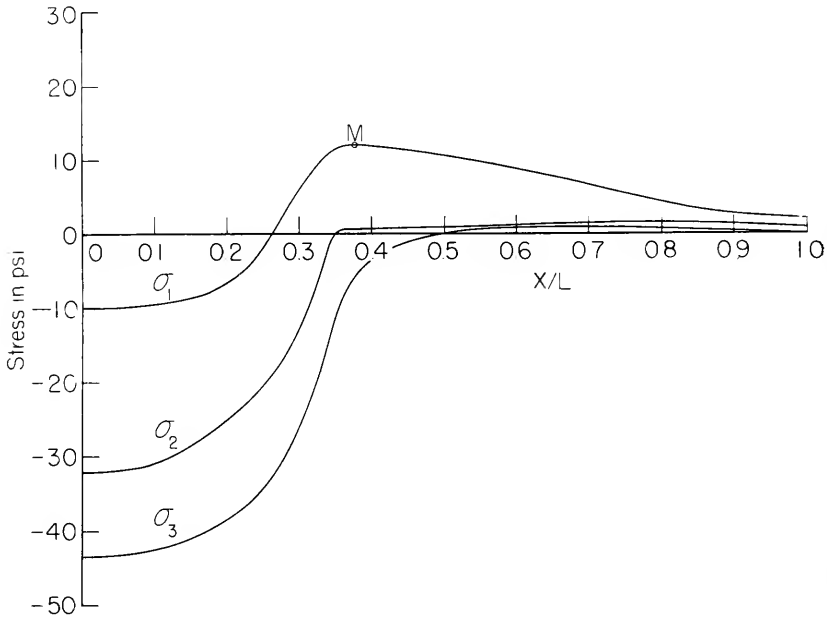

Fig. 13—Principal stresses for line G–G. Vertical load 78.4 lb.

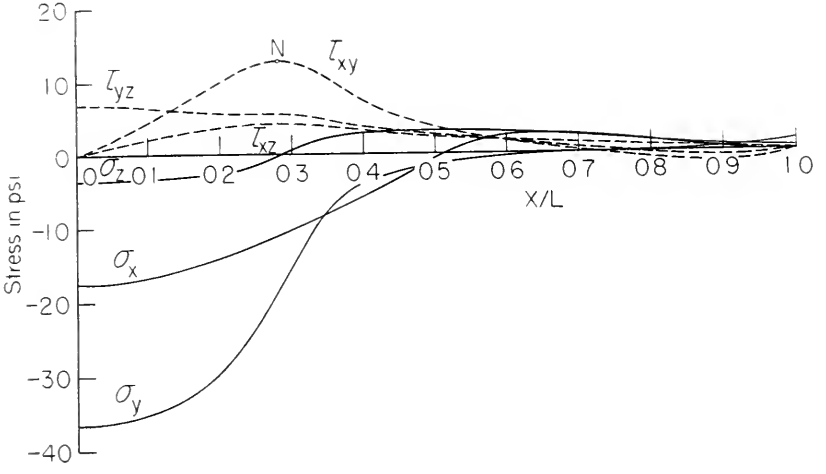

Fig. 14—Rectangular stress components for line H–H. Vertical load 78.4 lb.

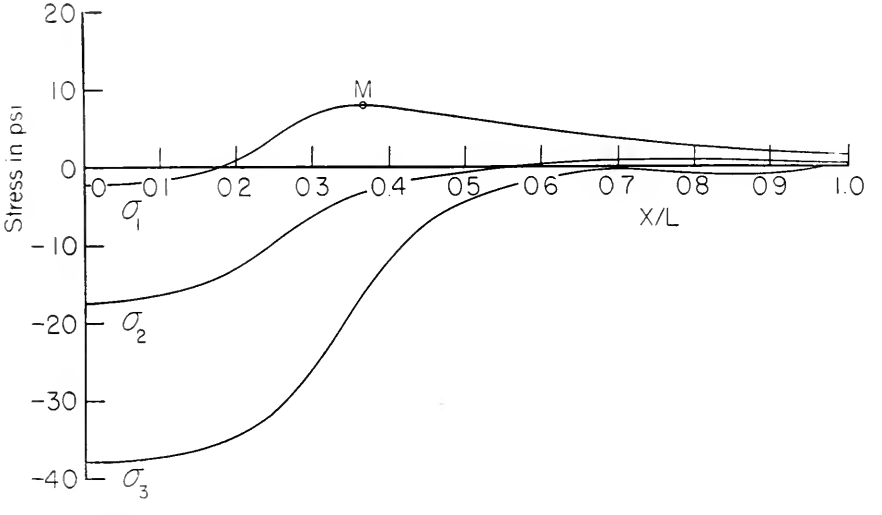

Fig. 15—Principal stresses for line H–H. Vertical load 78.4 lb.

Report on Assignment 9

Recent Developments Affecting Rail Section

J. A. Bunjer (chairman, subcommittee), W. D. Almy, S. H. Barlow, T. A. Blair, T. F. Burris, C. J. Code, L. S. Crane, W. J. Cruse, C. E. R. Haight, C. J. Henry, S. R. Hursh, W. M. Jaekle, K. K. Kessler, Ray McBrian, R. B. Rhode, H. F. Whitmore, R. P. Winton, Edward Wise, Jr.

This is a progress report, presented as information.

A request was made in February 1957 upon the chief engineers of AAR Member Roads to have measurements made of the actual loss in height due to wear, of rail being removed from main line tangent track during 1957. A rail wear data sheet accompanied the letter, and the request was made that rail on main line tangent track only and laid new originally in its present position be measured. The letter requested that data be furnished for the rail section, year rolled, approximate annual traffic density in gross tons, measured height of rail to nearest 1/32 in at the mid-width of the rail and away from rail end batter or wheel burns, and the loss in height of rail. Twenty railroads responded with complete data, and the number of individual measurements ranged from 1 to 79 per road, with a sum of 380 measurements. The following rail sections predominated in the measurements: 100, 110, 112, 113, 130, 131, 132, 140 and 152–155 lb. The railroads furnishing complete data were UP, KCS, C&O N&W, CP, C&EI, Sou., Maine C, D&H, Seaboard, Soo Line, Nickel Plate, IC, Erie, CB&Q, T&P, CN, NYC, SP and PRR. The PRR furnished contours of twenty-six 140-, 152- and 155-lb sections with complete data.

The rail wear data in terms of tonnage is plotted in Fig. 1. The ordinate is rail-head wear in inches per 100 million gross tons of traffic, and the abscissa is the average annual traffic density in million gross tons of traffic on rails. In Fig. 1, the plotted triangles represent the average of all individual measurements within limited areas. A mean curve is drawn close to the plotted averages. The slope of the mean curve is quite steep between 2 and 10 MGT per year traffic. At 13 MGT per year, the mean value is 0.030 in head wear per 100 MGT traffic and reduces in a straight line variation to 0.023 in at 40 MGT per year traffic. At the lower annual tonnages, the scatter of individual measurements is quite wide. For annual tonnages above 13 MGT where the mean curve becomes a straight line, the scatter of individual measurements becomes much smaller. Above 12 MGT per year there are very few individual measurements above 0.045 in per 100 MGT of traffic. A few individual measurements at 2 to 4 MGT per year were above 0.120 in and were not plotted. Two Southern Pacific measurements at 32 MGT per year marked "heavy sand territory and variation caused by partially protected area of trees and buildings" were not plotted. Seven measurements on N&W 131–132-lb rails were not plotted because at removal from track their total tonnage carried was low.

The following is a list of roads furnishing data with a reported annual traffic of 20 MGT or more at some measured locations:

Road	*Readings*	*Rail*	*MGT/Ycar*	*Max MGT*
UP	15	131,	19 to 40	585
C&O	18	110, 112, 131, 132	5 to 42	420
N&W	19	131, 132	19 to 50	600
Sou.	38	100, 130, 131	13 to 22	360
D&H	15	112, 130, 131	1.4 to 21	340
IC	18	112	7 to 31	460
Erie	11	110, 112, 130, 131	0.5 to 26	700
SP	15	113	23 to 37	390
PRR	29	130. 131. 140. 152, 155	7 to 43	900

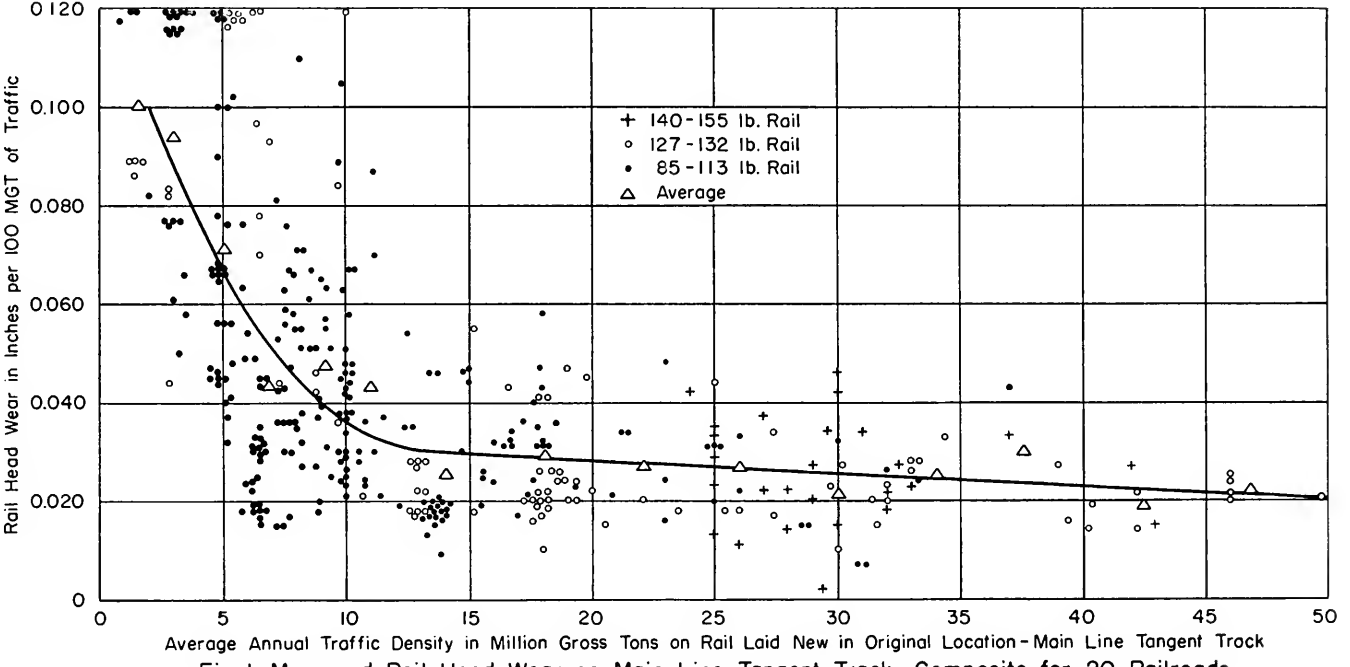

Fig. 1 - Measured Rail Head Wear on Main Line Tangent Track - Composite for 20 Railroads

The data plotted in the figure represent roads rather well distributed throughout the country. Without doubt, local conditions on the above tangent tracks vary widely on individual railroads and certainly from one road to another. The data also include rails from 85 to 155 lb, but, of course, the high tonnages reported are on the heavier rail sections.

In the first service test of joint bars conducted from 1937 to 1948, rail head wear was measured on several hundred rails. The rail head wear averaged on the Santa Fe 112-lb section 0.030 in per 100 MGT of traffic and on the Pennsylvania 131-lb section 0.026 in per 100 MGT of traffic.

If rail head wear on main line tangent track can be assumed to follow the mean curve for traffic densities shown in Fig. 1, then for varying traffic densities and a total rail life in its original tangent position varying from 150 to 500 MGT of traffic, the total head wear would be expected to vary from 0.100 to 0.140 in for the conditions in the following tabulation:

Traffic MGT/yr	*Wear-In per 100 MGT*	*Years Service*	*Total MGT*	*Total Head Wear-In*
5	0.067	30	150	0.100
10	0.036	30	300	0.108
20	0.028	25	500	0.140
30	0.025	16⅔	500	0.125
40	0.023	12½	500	0.115

Report on Assignment 10

Service Performance and Economics of 78-Ft Rail; Specifications for 78-Ft Rail

Collaborating with Committee 5

J. K. Gloster (chairman, subcommittee), W. D. Almy, E. L. Anderson, S. H. Barlow, T. A. Blair, B. Bristow, R. E. Catlett, Jr., L. S. Crane, W. J. Cruse, C. J. Henry, S. R. Hursh, J. C. Jacobs, W. M. Jaekle, N. W. Kopp, Ray McBrian, B. R. Meyers, R. B. Rhode, E. F. Salisbury, W. D. Simpson, H. F. Smith, A. P. Talbot, R. P. Winton, Edward Wise, Jr., J. E. Yewell, W. L. Young.

This is a progress report, presented as information.

Foreword

This report covers only the service tests of 78-ft rail installed in August 1956 by the Illinois Central Railroad in its southward main track (No. 1 of 3 tracks) south of Monee and Peotone, Ill. The purpose of this test is primarily to develop information necessary to determine the rail anchorage required for adequately anchoring 78-ft rail. The rail anchorage used in the original 78-ft rail tests on the Pennsylvania Railroad near Hamlet, Ind., and on the Chicago & North Western Railway near Calamus, Iowa, had not proved to be satisfactory. The IC tests are reported in the Proceedings, Vol. 58, 1957, page 1048, and Vol. 59, 1958, page 992.

The field work and preparation of the test report were conducted by the AAR Engineering Division research staff under the direction of G. M. Magee, director of engineering research, under the direct supervision of H. E. Durham, research engineer track and members of his staff.

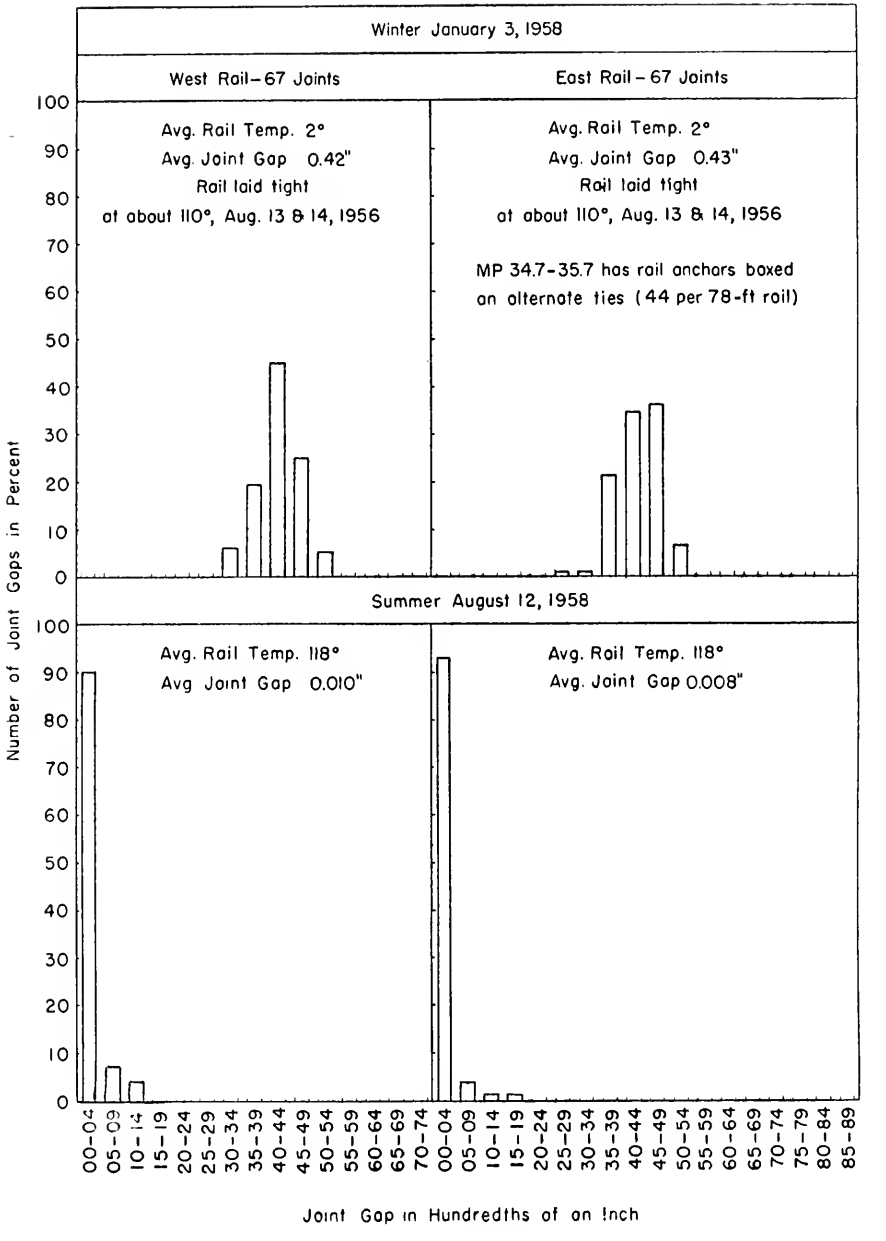

Fig. 1. Summer and Winter Joint Gap Measurements in 78 ft Rail MP 34.7-35.7 ICRR between Monee and Peotone, Illinois.

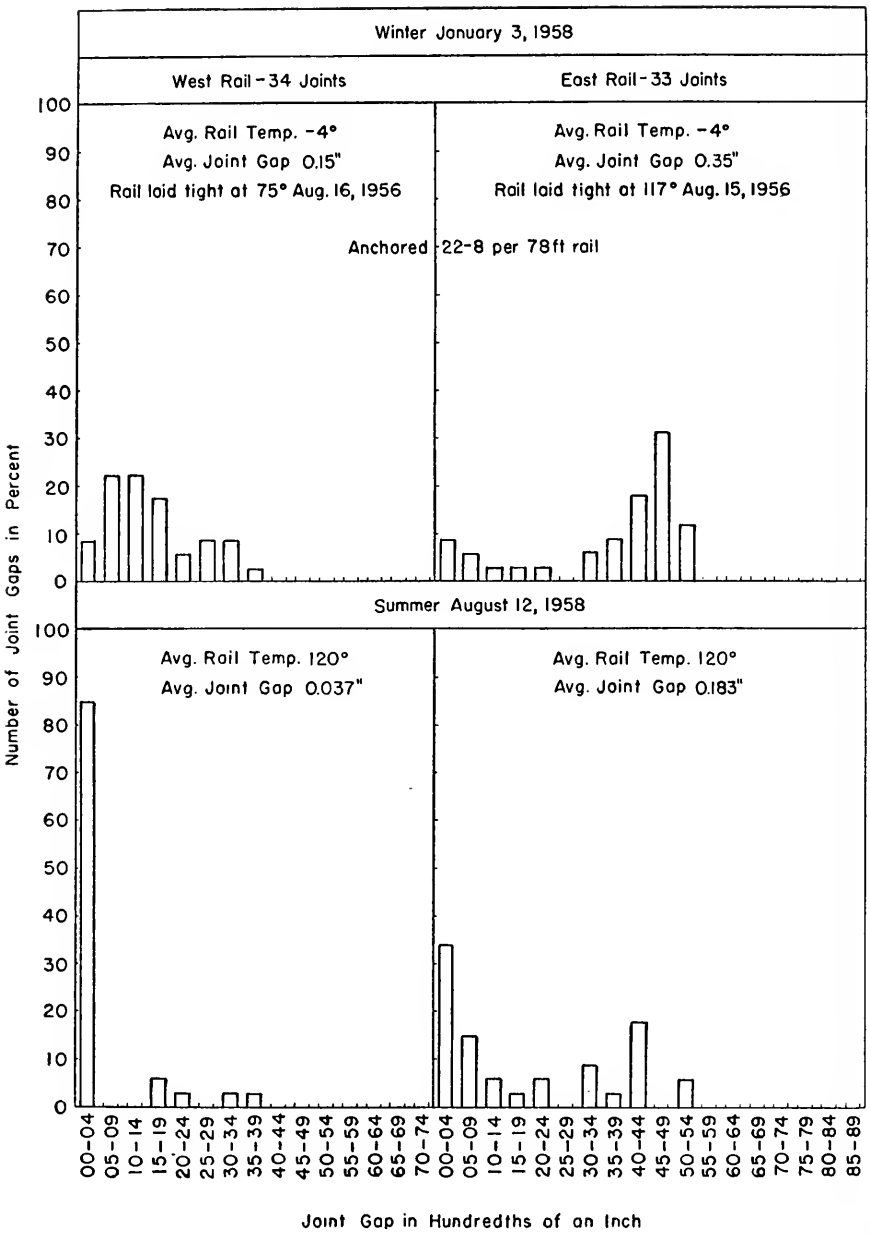

Fig. 2. Summer and Winter Joint Gap Measurements in 78ft Rail MP 42-42.5 ICRR between Monee and Peotone, Illinois.

Discussion of Test Data

Figs. 1 and 2 show winter and summer joint gap bar diagrams for the two sections-M.P. 34.7–35.7 and M.P. 42–42.5, in the southbound track of the Ilinois Central.

The AAR test mile, M.P. 34.7–35.7 (Fig. 1), shows essentially the same gap pattern as in 1957. With winter temperature of 2 deg in 1958 compared to 1 deg in 1957. the average gap increased 0.03 in whereas the average summer gap was 0.01 in less at 118 deg in 1958 than at 113 deg in 1957. As in 1957, the gaps in the one-half mile, M.P. 42–42.5 (Fig. 2), lack the uniformity of the test mile which continued to indicate the importance of sufficient anchorage reverse to traffic. (Compare the east rail in Fig. 2 with Fig. 1). As in 1957, the west rail, M.P. 42–42.5, shows the lesser variation between average winter and summer gaps, reflecting the advantage of laying rail at more nearly a mean rail temperature.

Maintenance

No maintenance work pertinent to the test has been performed since the track was surfaced shortly after laying in 1956.

Acknowledgement

The Association is grateful to the Illinois Central for its cooperation and assistance in carrying out the service test.

Report on Assignment 11

Rail Damage Resulting from Engine Burns; Prevalence; Means of Prevention; Repair by Welding

C. E. Morgan (chairman, subcommittee), E. L. Anderson, F. W. Blitz, T. A. Blair, C. J. Code, C. A. Colpitts, L. S. Crane, W. J. Cruse, G. H. Echols, J. K. Gloster, C. E. R. Haight, V. E. Hall, J. C. Jacobs, K. K. Kessler, N. W. Kopp, Lee Mayfield, Ray McBrian, C. R. Riley, E. F. Salisbury, W. D. Simpson, A. P. Talbot, R. P. Winton, Edward Wise, Jr.

Presented as information, this report presents a tabulation of engine burns welded as well as welded engine burns that broke during 1957. The slight increase in the number that broke in 1957 compared to the total of 116,403 welded gives further proof that welding engine burns is a very sound and economical procedure.

Wheel burns that were welded with joint bars applied are not included in the table.

Rail cleaning solutions to remove grease show some promise in improving the adhesion factor between locomotive and rail. Some tests have shown that 7 to 10 percent more tonnage can be handled in certain bad areas by cleaning the top of the rail.

WELDED ENGINE BURNS AND FAILURES REPORTED PRIOR TO DECEMBER 31, 1954
TO DECEMBER 31, 1957

Railroad	Total Engine Burns Welded Prior to Dec. 31, 1954	Number of Engine Burns Welded During 1956	Number of FWEB's During 1956	Number of Engine Burns Welded During 1957	Number of FWEB's During 1957
AT&SF	920	12,883	0	22,023	0
B&O	101	603	0	289	0
C&O		11,368	5	6,408	8
C&NW	3,371	3,672	0	1,996	0
D&H	7,160	51	1	131	1
EJ&E	Did Not Report	9,174	0	8,125	1
IC	5,354	547	0	1,018	0
PRR	98,447	49,953	7	73,719	11
RF&P	11,563	205	2	0	0
St. L - SF	619	484	0	182	0
SAL	4,946	1,287	0	584	0
Southern (Sys.)	No Record	No Record	2	No Record	0
Southern (West. Div.)	123,408	5,648	1	1,928	0
TOTALS	255,889	95,875	18	116,403	21

*FWEB - Fractured or Failed Welded Engine Burn

Total Number of Engine Burns Welded in 1955 65,001
Total Number of Welded Engine Burn Failures in 1955 15

PROCEEDINGS

PROGRAM

Fifty-Eighth Annual Meeting

Sherman Hotel, Chicago

Monday, March 9

Morning Session—Grand Ballroom—9:30 to 12:00

Invocation—Rev. Robert F. Truesdell, Congregational Church, Winnetka, Ill.

Introductions and Greetings.

Presidential Address—B. R. Meyers, Chief Engineer, Chicago & North Western Railway.

Report of Executive Secretary—Neal D. Howard.

Report of Treasurer—A. B. Hillman, Chief Engineer, Chicago & Western Indiana and Belt Railway of Chicago.

Greetings from the Signal Section, AAR, V. P. Shepardson (Chairman), Engineer Signals and Communications, Richmond, Fredericksburg & Potomac Railroad.

Greetings from the Electrical Section, AAR, H. P. Wright (Chairman), Electrical Engineer, Baltimore & Ohio Railroad.

Greetings from the National Railway Appliances Association, R. A. Carr (President), Dearborn Chemical Company.

Keynote Address—Change and Challenge in Railroading, by D. P. Loomis, President, AAR.

Address—Give the "High Ball" to Safety, by Paul Jones, Director of Public Information, National Safety Council.

Presentation of Honorary Membership Certificate to Dr. L. K. Sillcox, Honorary Vice Chairman of the Board, New York Air Brake Company.

Address—What I Observed in Europe of Interest to the American Railroads, by Ray McBrian, Director of Research, Denver & Rio Grande Western.

Address—Summary of Discussions Before Industry Conference on Railway–Highway Problems, by H. H. Hale, Assistant to Vice President—Highway Transportation, AAR.

Afternoon Session—Grand Ballroom—2:00 to 5:00

Reports of Committees	Bulletin Numbers
9—Highways (2:00)	546
Address—AASHO Road Test Being Carried on in Illinois (illustrated), by W. N. Carey, Jr., Chief Engineer for Research, AASHO Road Test.	
20—Contract Forms (2:40)	546
11—Engineering and Valuation Records (2:55)	548
14—Yards and Terminals (3:15)	546
Motion pictures of facilities for loading and unloading rail–truck freight equipment.	
16—Economics of Railway Location and Operation (4:05)	546
Address—Economics of Railway Engineering, by Frank J. Richter, Publisher, Modern Railroads.	
25—Waterways and Harbors (4:50)	547

Tuesday, March 10

Morning Session—George Bernard Shaw Room—9:00–12:00

Reports of Committees	Bulletin Numbers
24—Cooperative Relations with Universities (9:00)	548
Address—The Engineer's Responsibility to Railroad Management by R. G. May, Vice President, Operations and Maintenance Department, AAR.	
13—Water, Oil and Sanitation Services (9:40)	546
Address—The Broadening Field for Railway Water Service Engineers, by E. T. Myers, Engineering Editor, Modern Railroads.	
7—Wood Bridges and Trestles (10:15)	548
Address—How Serviceable Are 50-Year Old Bridge Stringers, by F. P. Drew, Assistant Research Engineer Structures, AAR.	
8—Masonry (10:30)	547
Address—Prestressed Concrete in Western Europe and Russia (illustrated), by Ben C. Gerwick, Jr., President, Ben C. Gerwick, Inc.	
30—Impact and Bridge Stresses (11:10)	547
15—Iron and Steel Structures (11:25)	548

ASSOCIATION LUNCHEON—GRAND BALLROOM, 12 NOON

Presentation of those at speaker's tables.
Presentation of gavels to incoming committee chairmen.
Announcement of results of election officers.
Address by B. W. Heineman, Chairman, Chicago & North Western Railway, on Railroad Economics Today.

Afternoon Session—George Bernard Shaw Room—2:30 to 5:00

Reports of Committees	Bulletin Numbers
28—Clearances (2:30)	547
29—Waterproofing (2:40)	547
17—Wood Preservation (2:50)	547
6—Buildings (3:00)	546
Address—Practical Applications of Infra-Red Ray Heating to Railroad Buildings (illustrated), by L. R. Morgan, Assistant Research Engineer Structures, AAR.	
27—Maintenance of Way Work Equipment (3:25)	547
22—Economics of Railway Labor (3:55)	547
Address—Report on Work Study—A Tool for Railway Management, As Practiced on British Railways, by H. J. Fast, Assistant Chief Engineer, Canadian National Railways.	
3—Ties (4:35)	547
Address—Studies of Anti-Splitting Devices for Ties at the AAR Research Center (illustrated), by H. M. Sutcliffe, Research Technician, Research Staff, AAR.	

Wednesday, March 11

Morning Session—Grand Ballroom—9:00 to 12:00

Reports of Committees	Bulletin Numbers
Special Committee on Continuous Welded Rail (9:00)	549
4—Rail (9:15)	549
Address—Further Three-Dimensional Photoelastic Studies of Stresses in Rail Head Due to Wheel Contact Pressure (illustrated), by M. M. Frocht, Research Professor of Mechanics, Director of Experimental Stress Analysis, Illinois Institute of Technology.	
5—Track (9:55)	549
Address—Standardization of Turnouts—What Must Be Done to Achieve It?, by M. J. Zeeman, Engineer of Track Design, Santa Fe.	
1—Roadway and Ballast (10:45)	549
Address—Soil Engineering Problems on the Quebec, North Shore and Labrador Railroad (illustrated), by R. W. Pryer, Soils Engineer, QNS&L.	
Closing Business	
Installation of officers.	
Adjournment.	

Afternoon—1:30

Post-convention inspection of AAR Research Center.

Report of the Tellers

March 10, 1959

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the Nominating Committee, find the count of ballots as follows:

For President:

F. R. Woolford 1,656

For Senior Vice President:

E. J. Brown*

For Junior Vice President:

R. H. Beeder 1,650

For Directors (first four elected)

W. E. Cornell	971
F. L. Etchison	942
W. J. Cruse	914
C. R. Riley	876
H. B. Christianson, Jr.	746
V. C. Hanna	720
D. E. Rudisill	710
L. V. Johnson	623

For Members of Nominating Committee (first five elected)

J. E. Eisemann	1,030
W. D. Kirkpatrick	979
C. E. Weller	949
C. Neufeld	934
C. L. Towle	872
L. S. Crane	843
C. I. Hartsell	824
E. A. McLeod	736
P. D. Brentlinger	487
F. J. Corporon	413

The Committee of Tellers,
J. E. Wiggins, Jr., *Chairman.*

B. G. Anderson
C. M. Bardwell
R. A. Bardwelll
R. O. Bardwell
R. E. Buss
L. C. Collister
L. E. Conner
E. C. Cook
Raymond Dejaiffe
L. P. Diamond
A. E. Dulik
M. L. Edlund
J. W. Fulmer
C. J. Geyer
M. E. Giddings
C. S. Graves
R. R. Gunderson
F. E. Gunning
G. B. Harris
G. D. Hinton
N. W. Hutchison
Milton Jarrell
H. F. Kanute
J. R. Latimer
W. B. Leaf
E. J. Lisy
J. de N. Macomb
H. L. McMullin
C. R. Merriman
M. A. Michel
M. P. Oviatt
W. G. Park
H. C. Pottsmith
R. S. Radspinner
C. L. Robinson
C. W. Russell
R. L. Samuell
R. K. Seals
R. S. Shaw, Jr.
T. A. Tennyson, Jr.
R. E. von Sprecken
K. E. Wyckoff
G. L. Zipperian

* Under provisions of the Constitution, E. J. Brown advances automatically from junior vice president to senior vice president.

PROCEEDINGS

Running Report of the Annual Meeting of the American Railway Engineering Association (Construction and Maintenance Section, Engineering Division, Association of American Railroads), March 9–11, 1959, Hotel Sherman, Chicago, Including Abstracts of All Discussions, All Formal Action on Committee Presentations, Specific Papers and Addresses Presented in Connection with Committee Reports, and Other Official Business of the Association

Opening Session—March 9, 1959

President B. R. Meyers,* presiding

The opening session of the 58th Annual Meeting convened at 9:30 am.

EXECUTIVE SECRETARY NEAL D. HOWARD: Gentlemen, it's getting pretty nearly time to start. I hope that those standing in the back of the room will find seats promptly so we won't be delayed.

While you are finding your places, President Meyers has asked me to invite our past presidents, our officers, our directors and several of our special guests to come to the platform. Will these men please take their places as indicated by the different signs here at the speaker's table? The directors on my left, and on my right, our past presidents and some of our special guests who will participate in this morning's program.

While these gentlemen are coming to the speaker's table, may I ask that the members of any committees that have luncheons planned for this afternoon who have not already purchased their tickets for those luncheons do so before this session starts because you must have a ticket in order to participate in the luncheon, and we must know well in advance how many are going to be at each luncheon.

I see down in front of me Mr. Bering, chairman of the board of the Sherman Hotel Corporation. He has a gavel which he would like to present to our president so that this meeting will get off to a good start. Mr. Bering, would you come up at this time and make your presentation?

MR. FRANK BERING: Thank you. Mr. President, members of the American Railway Engineering Association: I can't tell you how happy we are to have you back with us again. We are very appreciative, and if there is anything that we can possibly do for anyone, please call upon us.

[President Meyers came forward.]

Now, Mr. President, on behalf of the Hotel Sherman, I wish to present to you this gavel. May it serve you well during your deliberations, and then may you take it home as a remembrance of the finest convention you have ever held. Thank you.

[Applause]

PRESIDENT MEYERS: Thank you, Mr. Bering. This is indeed a very fine gavel, with a lot of engraving. I will have to read it at my leisure.

Will the meeting please come to order.

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* Chief Engineer, Chicago & North Western Railway.

This is the 58th Annual Meeting of the AREA and the concurrent annual meeting of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads.

As we begin our two and one-half days of serious deliberations in behalf of an industry which is essential to the welfare of our country, and one which is so closely linked to the individual lives of each of us, it is very fitting and desirable that we seek divine guidance and help. Accordingly, I have asked Reverend Robert F. Truesdell of the Winnetka Congregational Church, to do this for us. Reverend Truesdell.

Invocation

[The assembly arose]

REVEREND TRUESDELL: Most gracious God, our Heavenly Father, on this notable occasion gladly do we pause and acknowledge Thee as our Creator, and as the one who gives meaning to all of our activities. We also bring Thee our thanksgiving for this beloved land of ours where dignity of personality and freedom and moral and spiritual values still have profound meaning and the respect of our people and government alike.

We thank Thee, too, for the initiative, resourcefulness, the adventuresomeness that have been the cornerstones of our free enterprise system, and for the great industry of American railroading which has made such an invaluable contribution to the growth and present greatness of our country.

May this industry go on from strength to strength and continue mightily in the building of a better America and indirectly a better world.

Now may Thy rich blessing rest upon all those men and women from every corner of our land who have assembled here for this important convention and may all of its sessions be most rewarding. Amen.

PRESIDENT MEYERS: Thank you, Reverend Truesdell. We appreciate your petition in our behalf. We shall be happy to have you remain with us as long as you desire, but we want you to feel at liberty to leave at any time you feel you have to. Thank you again for meeting with us this morning.

We meet here today under improved economic conditions, but we are all aware that there is still much to be done to improve the state of our industry. We, as an Association, have a definite responsibility in this regard. We accept that responsibility. That is why we take two and one-half days away from our regular jobs to meet here to analyze our problems and to think out their solutions together.

Our convention hotel, as was demonstrated last year, provides splendid facilities for our activities, and its management and personnel have assured us every courtesy and service. This, combined with long and careful planning on the part of our officers and directors, your secretary's office, and your Committee on Convention Arrangements, insure another most successful and profitable meeting for all of us.

As you know, there is no exhibit of the National Railway Appliances Association in connection with our convention this year, but I am pleased to see so many of our railway supply friends here, with whom we can exchange greetings and discuss our problems. We have a long and interesting program ahead of us which will fill every minute of the next two and one-half days—in fact, so much so that it is essential that we start all of our sessions on schedule and that committees adhere strictly to the amount of time allotted to them for their presentations.

Without an exhibit, it is hardly to be expected that the attendance at our con-

vention this year will equal the near record attendance at our last convention, but you will be interested to know that in order to participate in certain pre-convention activities, members and guests—a total of 316—registered yesterday between 11 am and 3 pm. The names of those who registered appear in the first of the three Daily Registration Lists, which will be available shortly.

I am glad that a considerable number of you brought your wives along to the convention and am pleased that a number of them are with us this morning in the balcony. [Looking up at the ladies] We want you to know that you are welcome to attend any of our sessions. The balcony will be continuously available to you for this purpose, and you can slip in and slip out as you desire. Many of you will be especially interested in the Closing Business Session of the convention beginning about 11:30 am on Wednesday, when our new officers will be installed. In the meantime, I hope you will enjoy the special functions which have been arranged for you and that you will have a generally pleasant time in Chicago.

Before starting the more formal part of our program this morning, I would like to present to you those sitting at our speaker's table. As I call their names, I will appreciate their standing, and please, no applause until we get all done.

Mr. H. S. Loeffler, past president of AREA, 1950–1951; assistant chief engineer, Great Northern Railway, St. Paul, Minn.

Mr. T. A. Blair, past president of AREA, 1951–1952; retired chief engineer system, Atchison, Topeka & Santa Fe Railway, Park Ridge, Ill.

Mr. C. J. Geyer, past president of AREA, 1952–1953; retired vice president, construction and maintenance, Chesapeake & Ohio Railway, Richmond, Va.

Mr. G. W. Miller, past president of AREA, 1954–1955; general superintendent, Canadian Pacific Railway, Toronto, Ont.

Mr. G. M. O'Rourke, past president of AREA, 1955–1956; retired assistant engineer maintenance of way, Illinois Central Railroad, Chicago.

Mr. Wm. J. Hedley, past president of AREA, 1956–1957; chief engineer, Wabash Railroad, St. Louis, Mo.

Mr. Ray McBrian, past president of AREA, 1957–1958; director of research, Denver & Rio Grande Western Railroad, Denver, Colo.

Mr. E. J. Brown, junior vice president of AREA, chief engineer, Burlington Lines, Chicago.

Mr. F. R. Woolford, senior vice president of AREA, chief engineer, Western Pacific Railroad, San Francisco, Calif.

Mr. Neal Howard, executive secretary of AREA.

Mr. A. B. Hillman, treasurer, AREA; chief engineer, Belt Railway; Chicago & Western Indiana Railroad, Chicago.

Mr. G. H. Echols, director of AREA; chief engineer, Southern Railway System, Washington, D. C.

Mr. L. A. Loggins, director of AREA; chief engineer, Southern Pacific Lines in Texas and Louisiana, Houston, Tex.

We had hoped to introduce next Mr. R. R. Manion, director of AREA; assistant vice president—operation, New York Central System, but he could not be here today.

Mr. W. G. Powrie, director of AREA; chief engineer, Milwaukee Road, Chicago.

Mr. A. V. Johnston, director of AREA; chief engineer, Canadian National Railways, Montreal, Que.

Mr. W. H. Hobbs, director of AREA; chief engineer, Missouri Pacific Railroad, St. Louis, Mo.

Mr. A. B. Stone, director of AREA; chief engineer, Norfolk & Western Railway, Roanoke, Va.

Mr. J. C. Jacobs, director of AREA; engineer maintenance of way, Illinois Central Railroad, Chicago.

Mr. W. W. Hay, director of AREA; professor of railway civil engineering, University of Illinois, Urbana, Ill.

M. W. M. Jaekle, director of AREA; chief engineer, Southern Pacific Company, San Francisco, Calif.

Mr. T. F. Burris, director of AREA; chief engineer, system, Chesapeake & Ohio Railway, Huntington, W. Va., and

Mr. T. M. von Sprecken, director of AREA; assistant to chief engineer, Southern Railway System, Washington, D. C.

[Applause]

In the introductions thus far, I purposely skipped over three special guests whom I will introduce a little later in the program and ask for a word of greeting from their respective organizations.

The first official business to come before our meeting is consideration of the minutes of the 1958 convention which were printed in Vol. 59 of the AREA Proceedings for 1958, a copy of which was furnished to each member. Unless I hear some objection or correction to these minutes, we will dispense with the reading.

Hearing no objections or corrections I declare the minutes approved as printed in the Proceedings.

Address of President B. R. Meyers

I would like to take a few minutes at this time to summarize some of the events during the past year and make some comments about the future as I see it.

Our Association has had a most interesting year. We have had our problems, but over-all we have had a good year. Our membership of some 3400 has held relatively steady, except for a very slight decrease, which was not unexpected in a recession period. However, I would like to point out that there has been no reduction in the number of members on committees.

Our finances are in good condition, although it appears we may have an unbalanced budget for the coming year due to some non-recurring expenses.

Our national economy is again expanding after a recession which hit bottom last summer. Business in general and railroad business in particular is leaving the recession behind. An increase is predicted in carloadings which should reflect in most roads doing more work on their fixed property. It is interesting to note that during the recession year of 1958 the average wages paid railroad employes reached a new all-time high. Excessive wage demands by unions in future negotiations could very well do serious damage to the welfare of our industry. This situation makes it mandatory on all of us to increase our efforts to reduce unit costs by mechanization and all other possible means in order to get more for each dollar expended and thus increase the net for our companies.

We have 142 reports from our 23 standing and special committees, which have already been published in the Bulletins. This is not unusual as our committees have been working hard for many years. As time goes on the personnel changes, the number of committees change and their assignments change to keep abreast of our fast-changing technology. However, the interest, enthusiasm and willingness of men interested in rail-

road construction and maintenance, working together on the solution of our common problems, is the sustaining reason for this Association. I can say this with assurance, as I have visited a good many of the committees during this past year and observed them at work.

These committee reports, together with a number of special features, should provide a very interesting program at this convention from which we can all derive considerable benefit for ourselves and for our companies.

While I am mentioning committees, I want to acknowledge the able job accomplished by the Arrangements Committee under the direction of General Chairman Jim Barnes and to thank all of the members, on behalf of the Association, who have worked on this committee.

I would like to express my appreciation to Simmons–Boardman Publishing Corporation for again operating a coffee bar during our convention. I am sure this has helped get some of our members to the opening sessions on time.

During the year we have tried to keep you informed on the affairs of your Association through the AREA News. We gave you information on matters pending in Congress, and we were pleased to see that some legislation helpful to the railroad industry was enacted. I am sure most of you did your part in supporting these measures and will do so in the future at the proper time. You should be just as alert to oppose proposed legislation harmful to our industry. We have a duty and obligation to our industry beyond our specific technical responsibilities and should not be reluctant to do our part in helping to solve the over-all problems of the railroads.

At the convention a year ago considerable emphasis was placed on the need for expanding our research. In my opinion, this is just as important today and should be kept in mind constantly by our committees. Our research in 1958 cost approximately $550,000. The work was carried out under the able direction of the AAR Research Staff headed by Vice President W. M. Keller and Director of Engineering Research G. M. Magee. As you know, our research is financed by an appropriation from the Association of American Railroads, with some assistance on specific projects by the American Iron and Steel Institute. It is hoped that our research can be expanded in the future.

Our research program is limited by available funds and up to now has been used to a great extent for technical services, testing, investigations, etc., which are necessary for the day-to-day operation of our railroads. While all of these are part of the broad term "research," I feel we are all in agreement that it would be desirable and worthwhile to take more advantage of the basic type of research.

Technology is advancing very fast, and there would appear to be many applications for the benefit of the railroad industry if funds for sufficient research could be obtained to explore the feasibility of such applications. The potential benefits that could develop from atomic power, nuclear light sources and many other discoveries will accrue to those industries which have the foresight to thoroughly investigate them. In fact, an accelerated research program now could well be the key to the railroads remaining in a competitive position with other forms of transportation 10 or 15 years from now.

I know that our research staff is following closely the new developments in basic and fundamental research to the extent possible with available funds in order to take advantage of any possible applications for railroad use. I would urge each member of this Association to also be alert and suggest to the appropriate committee or the research staff possible applications of any new technology that may come to your attention or occur to you.

A little over a year ago a Board Committee on Research was established. This

committee, has functioned very well and has efficiently handled all matter pertaining to our expanding research program. The board has received much help and council from this committee, and its importance to the Association will increase in the future.

I want to compliment the railroad equipment industry on its progress in developing new machines which reduce manpower requirements and in many cases produce better work; however, in my opinion, we have only scratched the surface on developments in this field. It is suggested that railroad equipment manufacturers step up their research. Increased sales will be the reward to the leaders.

As a result of changes in our constitution approved last fall by letter ballot, we now have an Executive Committee which has the authority to act for the Board of Directors when urgent problems arise which cannot wait for a regular meeting of the Board. This change should strengthen the executive branch of your Association.

One of the highlights this past year was the privilege of holding our November Board meeting on the engineering campus at Urbana and presenting, jointly with the American Iron and Steel Institute, a large bronze plaque to the University of Illinois. This plaque was hung in Talbot Hall and is in honor of Professor H. F. Moore for his outstanding research in metallurgy and the causes of transverse fissures in railroad rails.

Personnel is probably the most important commodity on our railroads today. Because we have used up our supply, Committee 24 has spent considerable time this last year revising and modernizing our recruitment brochure, and the Board at its last meeting authorized an expenditure of approximately $5000 for printing a three-year supply. I feel this is important to the railroads in helping to interest young engineers in railroad employment. We must sell our industry to the young college graduates the same as other industries are doing, or be left by the wayside. I mention this recruitment brochure also because it represents a substantial part of the non-recurring expenditures we will have in the coming year.

In the October 1958 issue of the AREA News I outlined my thoughts on the potential savings to the railroad industry by standardization. Industry in general has recognized and taken advantage of the inherent advantages in standardization, but the application in the railroad field has been comparatively slow.

Through the years considerable progress has been made in this regard, but we still have a long way to go. I am not unaware of the problems and difficulties in making further substantial progress in this field, but if we do not make a determined effort our industry will continue to be the loser. When thinking of standardization, our first thoughts are directed to materials, equipment and other similar products, such as rail sections and trackwork. However, we should not cut off our thinking with these items. Every committee in the AREA should examine its field with a critical eye to see where standardization or simplification could benefit the railroad industry.

As an example to illustrate what I am talking about let's take a look at a few items. Are you aware that the mills have been called upon to roll 43 different rail sections in recent years? The total investment in these rolls is approximately 12 million dollars, with an annual cost of almost one-half million dollars for interest alone. Also consider the production time lost and the cost when changing rolls in the rolling mills.

The variation in design of angle bars has been equally large. In addition, a check of three mills indicates that railroads have required 42 different sizes of bolt holes in these angle bars. A review of track bolts and nuts indicates a similar multiplicity of designs.

The cost of track ties is one of the large items of expense. How much could be saved if we could agree now on one method of treatment, one method of controlling end checks, and greatly reduce the number of templates for drilling.

This seems an opportune time to do some serious thinking about these things, and I am happy to report that new assignments have been given to the Rail and Track committees covering investigations and studies of rail sections and trackwork. It is the hope of the Board that these assignments will be progressed vigorously and with an open mind to the end that we can reduce the number of our standard rail sections and trackwork plans.

It is also hoped that when this work is completed all of the railroads will see fit to adopt the standards recommended so that the industry in due time can realize the many benefits possible through standardization. If we do not follow through on such a program, it seems to me that we, both as individual engineers and as an Association, are open to serious criticism.

In conclusion, I would like to express my appreciation for the help and cooperation received from the secretary's office and the research staff during my year as president. There is a great deal more detail work done behind the scenes by these two organizations than most of you realize, and they deserve the thanks of the entire membership.

I have enjoyed my work in the AREA very much and have considered it a privilege to direct this great Association during the past year.

Thank you for your attention. [Applause]

PRESIDENT MEYERS: The next order of official business is the report of our executive secretary, Mr. Howard.

Executive Secretary's Report

Mr. President, past and present officers of the AREA, members and guests:

With your permission, in view of the many important features remaining on our program this morning, I shall confine my remarks to a few highlights or matters which I consider of special importance. I know I have an obligation to make a verbal report to you at our Annual Meetings, but I feel justified in making this especially brief this year, both to give maximum time to our subsequent speakers, and because you have already been told some of the highlights of our past Association year.

But I do want you to know that, for the permanent record, your secretary has prepared the usual detailed written report, which covers the "water front" with respect to every phase of the Association's activities and operations during the past year. This is published in the March Year-Book Bulletin, copies of which were mailed to members on March 5, and which you will find on your desks when you return to them after this meeting, if you have not already received them.

One year ago at this time, with the railroads, along with the country as a whole, in the throes of an economic recession, the welfare of your Association for the year ahead, compared with the year just closed and immediately preceding years, was a matter of real concern to your officers and your secretary. Could the Association count on the continuing high level of interest and effort of its members and the support of the American railroads? Would it be able to continue unabated its productive work? And could it maintain its favorable financial condition?, were questions in the minds of all of us.

Now, 365 days later, the record happily shows all of these questions answered in the affirmative. The Association did retain the interest and productive effort of its members, and the backing of the railroads. It did continue its work unabated; and it did close the year in a not unfavorable financial condition, as will be pointed out by our

treasurer. In fact, in all of these respects—the adverse economic conditions during most of the year to the contrary notwithstanding—the Association moved into higher ground.

Only in the matter of total membership, as President Meyers has told you—did the Association take a backward step. Due largely to the inability of the railroads to augment their technical staffs with the usual number of new men, on the one hand, and an increased number of resignations from membership, resulting from the retirement of older members, on the other hand—the total membership of the Association dipped slightly during the year—unfortunately reversing an upward trend for the past 14 years, even though the increase in recent years has been relatively small. I do not consider this moving into higher ground in this particular respect, but I do feel that, the fact that this reduction in membership was not larger than it was under the conditions which prevailed, was also a favorable aspect of the Association year, and demonstrates that the AREA is not a fair-weather organization.

That I can make this generally favorable report to you was not the result of a "business as usual" attitude on the part of either the officers and directors of your Association, or you members generally. The more than 1100 of you on our technical committees are best aware of this, because, as you know, early in the year your officers and directors set in motion belt-tightening measures all along the line. These affected to some extent nearly all aspects of Association activity, especially committee activity, but were designed to have minimum adverse effect on the effectiveness and productivity of committees.

Time will not permit even enumerating these measures, but as most of you are aware, they resulted in carrying on a larger amount of work by correspondence; in fewer and shorter committee meetings, in more central meeting points, and in the elimination of all but essential inspection trips, which did not have the effect of extending meetings over an extra day. Through these means committee members were enabled to minimize their away-from-the-job time and expense in carrying forward the work of the Association.

At the same time, to increase its own efficiency, your Board of Direction sponsored and put into effect a number of things, including the creation of a five-man Executive Committee of the Board to function in its behalf between regular Board meetings on matters which cannot or should not be delayed; the giving of permanent status to the new Board Committee on Research which had been set up as a special committee early in the year; and continued to be represented through one of its members, insofar as possible, at committee meetings to maintain closer liaison with committees and their work.

With the assistance of the Engineering Division research staff, the work of our technical committees remained at a high level, as will be clearly evident to you in the character and number of reports to be made to this convention. This is also evidenced by the fact that these reports, as published in the recent issues of the Bulletin which have been made available to you, occupied a total of 768 pages—70 more pages than were devoted to committee reports presented to the 1958 convention—an increase which was occasioned in large part by a larger number of reports on assignments during the past year, rather than larger reports.

And as an indication that the value of the material in these reports goes far beyond the immediate membership of our Association, I would point out that during the Calendar Year 1958 more than 30,000 copies of Association publications were sent out from the secretary's office to, among others, the American railroads, colleges and universities,

students, Government agencies, engineers in industry generally, and railroad men in foreign countries.

Even these brief statements about the Association's work during the past year bear out, I am sure, my statement at the outset, that in 1958, despite the unfavorable conditions which prevailed throughout much of the year, the Association moved generally into higher ground during the past 12 months—with the single exception of total membership—to me a significant achievement. Continuing the same general policies, with continued support from the railroads individually and as a group—and with some emphasis on recouping the membership loss of the past year, there is every reason to expect that the Association will move forward to a still higher level of well-being and achievement in the year ahead. Thank you. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Howard.

In light of the things that have happened during the last year, I want to thank you and your staff for keeping things moving so that we could have this good report that you have just referred to.

Our next order of business is the report of our treasurer, Mr. A. B. Hillman. Mr. Hillman.

Treasurer's Report

At our Annual Meeting last year your treasurer stated that the prospects for a good year financially in 1958 were not too encouraging if the Association proceeded with its plan to purchase a several years' supply of Manual binders and published a second edition of the Association's Engineer Recruiting Brochure for distribution free to the engineering colleges and universities—especially if unfavorable business conditions continued throughout the entire year. But all of these things did not happen in 1958. The Association did purchase the required supply of Manual binders, but printing of the Brochure was necessarily delayed until 1959. At the same time—for the Association, at least—"business conditions" improved substantially during the last four months of the year, with receipts for this period considerably higher than anticipated, due primarily to the demand for the publications of the Association—particularly its Manual. As a result, receipts for the year exceed expenditures by $4,105.64. At the same time, the total assets of the Association at the end of 1958 were some $1500 higher than at the close of business in 1957.

It should be pointed out that the interest which the Association receives on the investments which it has accumulated over many years is a very important item of revenue each year. This is seen in the fact that in 1958 this interest amounted to $3,705—which accounts for more than 90 percent of the Association's net profit for that year. Over the past 20 years as a whole this interest, which amounted to $55,000, made the difference between the total net profit realized in these years of $33,618, and what would have otherwise been a deficit of more than $33,000.

It is well that, with its interest income, the Association enjoyed a good year financially in 1958, with an excess of Receipts over Disbursements of $4,105, if only to offset, almost in its entirety, the deficit of $4,401 sustained in 1957. In fact, it is especially fortunate that the Association realized this offsetting profit in 1958 since it is expected that, even with generally favorable conditions in 1959, and in spite of its interest income, the Association will incur a sizable deficit in that year due to increased costs for printing, salary adjustments, postage, office rental, and the publication of the revised Engineer Recruiting Brochure.

Supplementing these brief comments on my part as your treasurer, it occurs to me you will be interested in at least a couple of statements made by the Association's auditors with respect to finances of the Association, included in a letter to our executive secretary following the 1958 audit of the Association's books. Our auditors, as you may know, are Mr. C. A. Bick, vice president–operations, Monon, and Mr. P. D. Mitchell, chief traveling auditor of the Illinois Central. Their joint letter to our secretary, dated January 19, 1959, read in part, as follows:

"We have completed our check of the records and accounts for the year 1958 and found them satisfactory. The orderliness and exactness of the records is a credit to you and your organization.

"The investment account shows a gratifying increase and is an indication that your organization recognizes the importance of interest income as a source of revenue. Interest collections in the coming year will reflect the higher yield of bonds purchased and exchanged.

"It has been interesting to watch the growth of the Association through the years and we believe the accompanying financial statements are indicative of the direction and guidance which has resulted in a sound and progressive organization."

It is with some satisfaction that I am able to make this kind of a report this morning, and commend it to you for your acceptance. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Hillman.

We do not look with a great deal of anticipation to the deficit that we might have in 1959. Although we have talked a lot about it, you might think it was the national debt, but it isn't nearly that big. We have had bigger ones before, and in the year ahead it will be due largely to nonrecurring expenses.

As you may know, Mr. Hillman has been treasurer of our Association since 1953. After long and faithful service to his railroad, we understand that under the compulsory retirement plan of his company, he will retire from active railroad service on September 30 of this year. We are glad that the AREA has no comparable compulsory retirement plan for its treasurers, and Mr. Hillman will continue as treasurer at least for another full year. Thank you again, Mr. Hillman.

Gentlemen, you have heard the reports of our secretary and treasurer. I shall be glad to entertain a motion that these reports be accepted. Do I hear a motion, please?

[Motion was regularly made and seconded, was put to a vote, and carried.]

Greetings from the Signal and Electrical Sections, AAR

PRESIDENT MEYERS: It is highly appropriate that we should recognize at our speaker's table today representatives of the Signal and Electrical Sections of the Association of American Railroads, which as you know, are sister organizations of the AREA in making up the Engineering Division. I should now like to give them an opportunity to bring us a few words of greeting if they so desire, and I will call first on Mr. V. P. Shepardson, engineer of signals and communications, Richmond, Fredericksburg & Potomac Railroad, chairman of the Signal Section, AAR. Mr. Shepardson.

V. P. SHEPARDSON: Mr. President, members of the American Railway Engineering Association and guests:

I am privileged to greet you this morning on behalf of the Signal Section and to assure you the Signal Section has a real desire to cooperate and assist your committees in any way we can in the area of our specialization.

I am also proud that the Signal Section is recognized by the AREA at your annual meeting. In years past the signal department on many railroads had practically no

standing, but since those days signaling has changed in magnitude, character and significance, and today represents an important arm of the engineering department on many railroads. Your committees and our committees working together are solving problems that have annoyed both track and signal engineers for years. Cooperation and exchange of ideas and advice is necessary for us both to meet our responsibilities.

The management of my railroad recognizes the great value of the work accomplished at these meetings, and we are encouraged to take an active part in the proceedings. Railroad knowledge, like any scientific knowledge, must be sought and the interchange of ideas through committee association represents one of the very best mediums to bring about a better understanding of our problems.

The 1959 annual meeting of the Signal Section will be in Washington, D. C., October 12, 13 and 14. You are all invited, and to you whose responsibilities include the signal department on your railroad, please make it easy for them to attend. Thank you. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Shepardson.

It has been a pleasure for our Association to cooperate with the Signal Section, and we have an exchange of members who are collaborating with the different committees.

Now I would like to call on the chairman of the Electrical Section, Mr. H. P. Wright, who is electrical engineer of the Baltimore & Ohio Railroad.

H. P. WRIGHT: President Meyers, members of the AREA and guests: It is a pleasure and an honor to bring greetings to you from the Electrical Section, Engineering and Mechanical Divisions of the AAR, on the occasion of your 1959 convention. We cherish our partnership with your organization in serving our common objective, the welfare of the railroad transportation industry. Viewed in its perspective, a railroad is a machine for converting manpower, fuel and material into ton miles of transportation needed by our economy. The measure of our advance is to be found, therefore, in how new devices and new technologies, in combination, are used to produce better transportation service with maximum efficiency, maximum economy, and a minimum expenditure of manpower, fuel and materials.

It is a foregone conclusion that there is an abundance of very valuable information to be presented in your reports, to the benefit of the railroads and to the credit of those who helped prepare them. On behalf of the Electrical Section, I wish to thank your executive secretary, Neal D. Howard, for his continued valuable assistance and cooperation. Also to extend an invitation to you to attend the next annual meeting of the Electrical Section to be held here at Hotel Sherman, June 23, 24, and 25, 1959. I wish you an excellent meeting and thank you for the privilege of being with you at this opening session. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Wright. We hope that you and Mr. Shepardson will both convey our best wishes to your respective sections.

Greetings from the National Railway Appliances Association

PRESIDENT MEYERS: As you know, this is not an exhibit year. It seemed highly appropriate that we have at our speaker's table and recognize the president of the National Railway Appliances Association which puts on a large and instructive exhibit in connection with our convention every third year. The next one will be in March 1961. However, there will be one this fall in connection with the Roadmasters' and Bridge and Building Associations conventions. The current president of this association

is Mr. Robert Carr, president of Dearborn Chemical Company, and also president of RPI—Railroad Progress Institute. Mr. Carr, do you have a word for us at this time

ROBERT CARR: President Meyers, gentlemen of the American Railway Engineering Association, and ladies:

I thank you, Mr. Meyers, for bringing in my second job, the presidency of RPI. I am sure you gentlemen know about the banding together of the supply industry to work with, and promote the programs of, you railroad men in the interest of the railroad transportation industry in the United States. I believe that we have been helpful in RPI. I am sure that we can continue to be so.

However, it is my privilege to appear before you now as the representative of the National Railway Appliances Association. Our members enjoy the close and cordial relations that exist between our associations. It is a real privilege to be affiliated with you and to have a share in your activities toward the improvement of our fine railroad systems.

We look forward with confidence to having one of our best and most colorful displays at the time of your 1961 convention. In the meantime the Association of Track and Structures Suppliers is preparing a major exhibit to run concurrently with the meetings of the Roadmasters' and Maintenance of Way Association of America and the American Railway Bridge and Building Association being held in Chicago in September this year.

On behalf of all the members of the National Railway Appliances Association, congratulations and best wishes for the success of your 58th Annual Convention and thank you for this recognition. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Carr. We appreciate your greetings and also the fact that so many of your members are here at our convention.

With your permission, I should like to interrupt our proceedings for a moment to permit the Railway Age to take its usual convention photograph, but before it is taken, I would like to invite to the platform a number of special guests who will participate in the remainder of this morning's program because we would like to have these guests in our picture. I will be pleased if they will come to the speaker's table at this time.

[The convention photograph was taken]

PRESIDENT MEYERS: With the thought that those who have been sitting at our speaker's table thus far this morning will be more comfortable in the audience during the remainder of our program, I will excuse them at this time but ask that our special guests just invited to the platform remain here.

As you may have noticed, the special guests whom I have invited to the speaker's table include the keynote speaker of our convention and three of his associates in the AAR. I would like to present these gentlemen to you now. The others who will participate in our program later in the morning I shall introduce at that time.

First is Mr. R. G. May, vice president, Operations and Maintenance Department, AAR. [Applause]

Next, Mr. W. M. Keller, vice president, Research Department, AAR. [Applause]

Next, Mr. H. H. Hale, assistant to vice president, Highway Transportation, AAR. [Applause]

Introduction of Daniel P. Loomis

PRESIDENT MEYERS: Now, with all of the preliminaries out of the way, I know you are anxious that we get started on the real meat of our program, which I propose to do right now in presenting to you the keynote speaker of our convention. As you are all well aware our keynote speaker is Mr. Daniel P. Loomis, president and chief executive officer of the Association of American Railroads.

Mr. Loomis is no stranger to many of you because you will recall that as president and chief administrative officer of the AAR he was a guest at the Opening Session speaker's table of our 1958 convention, when Mr. William T. Faricy, then chairman of the Board of the AAR, was our keynote speaker.

And Mr. Loomis certainly needs no introduction to most of us in Chicago, because as head of the Association of Western Railways for a period of 15 years ending in 1957, with headquarters continuously in Chicago, many of us have known him for a long time through the strong and experienced leadership he gave that organization.

But for the benefit of those of our members and guests who have not known Mr. Loomis, I will briefly sketch his career. This I can do because his career is less notable for the number of positions he had held than for the distinction with which he held them. He was graduated from Union College in 1925 and received a law degree at Harvard in 1928. Immediately thereafter he entered the service of the Delaware & Hudson Railroad as an attorney, and by 1939 he had advanced to the position of assistant general counsel of that road.

From 1942 to 1948, Mr. Loomis was executive director of the Association of Western Railways at Chicago, an association which handles labor matters for the western railroads, and in 1948 when the Western Association of Railway Executives was merged with the AWR, he became chairman of the Association of Western Railways, the position he held when he was elected president and chief administrative officer of the AAR, on August 1, 1957. With the retirement of Mr. Faricy from the AAR on April 1, 1958, Mr. Loomis became president and chief executive officer of the AAR—the position he now holds. We are especially fortunate and honored that in his first year as head of the Association of American Railroads, Mr. Loomis has consented to be our keynote speaker. He will speak to us on the timely and challenging subject "Change and Challenge in Railroading." Gentlemen, Mr. Loomis. [The assembly arose and applauded]

Change and Challenge in Railroading

By Daniel P. Loomis

President, Association of American Railroads

A chance to speak before an audience of railroad engineering officials poses a challenge of a special kind. For the changes in railroading which you originate, and your ideas for still further changes, all have enormous effect on how railroads do their job today—and how they will do that job tomorrow.

I do not consider it an exaggeration to state that you engineers exert a controlling influence on the railroads' future. In this generation—and particularly in the nearly 14 years since the end of World War II—we have witnessed a veritable explosion in railroad technology. Great changes have been made—and we are on the threshold of introducing still greater changes—in motive power, rolling stock, traffic control systems, construction and maintenance methods and general operations. However, this great technological explosion has yet to be fully translated into the best in operating efficiency and services to the public.

The reason is not hard to find. Even though you engineers have shown us new concepts in railroading, management has been unable to carry through fully because of the virtual impossibility of raising adequate investment capital. Indeed, the technician points the way—but the level of industry earnings decides how far we can go.

This inescapable interrelationship, then, will serve as the springboard for my remarks today. Nothing is of more ultimate importance to the public when it comes to railroading than our improvement programs. For these affect as nothing else the quality of our services, the prices we charge, the jobs we create and our ability to continue as a vibrant progressive enterprise. It also follows that the public has high stakes in giving the railroads real opportunity to earn the money that makes modernization possible.

In the past 13 years railroads have spent more than $14 billion for new plant and equipment. That's a fabulous amount of money even in these times. It more than matches our net railway operating income for these years. It is half the industry's current net investment. It exceeds $17,000 spent for each present employee to provide better tools for doing a better transportation job. Even so, we feel we should spend an equal amount of money within just the next ten years, or even eight.

Yet look at what happened to capital spending last year. It was cut nearly in half from the $1.4 billion of 1957. That was a terrible setback for the railroads, and it produced untold hardships in slashed sales for suppliers and jobs for employees of both railroads and supply companies. Right now, railroads strain to make a comeback in this critical area. The lines have big backlogs of improvement projects on the drawing boards that have tremendous pay-off potentials in terms of better service at lower costs.

But where is the money coming from in an industry whose rate of return on net investment last year was only 2¾ percent? Where is the money coming from in an industry which, profitwise, ranks third from the bottom among the nation's 73 major industries and industrial groups? If we can find solid answers to this multi-billion-dollar question, we could wipe the slate clean of worries for our future.

Clues to where the essential funds can come from to make our plant and services more attractive to travelers and shippers and more responsive to the nation's over-all peacetime and war needs lie in a breakdown of that $14 billion of postwar investment. A third, or $4.6 billion, came directly out of net income—retained in the business and plowed back into improvements. Borrowing, mostly in the form of equipment obligations, accounted for $2.2 billion. A little more than another billion dollars was raised from other sources but mostly by drawing down working capital. And the remaining $6.1 billion, nearly half the total, significantly came from depreciation accruals—funds earmarked out of income for use in recovering investment property worn out in operations.

It is obvious, then, that the tax treatment of investment money is of crucial importance—and nowhere more so than in an industry where profits have shrunk so drastically. Significantly, the railroads' postwar tax payments to all government units almost precisely match their postwar capital spending for modernization. Think of the railroad system America would have today had any sizeable part of the tax load gone into improvements!

The industry desperately needs a better break on taxes. Whether it gets it or not will do much to decide where the railroads go from here.

The need to obtain more realistic tax treatment of money invested in new plant and equipment deserves more detailed comment. But right now, I would like for you to join me in looking at the other side of the capital improvement picture—operating expenses. After all, net income provides a large part of investment capital, and net income is

dependent on operating expenses as much as on revenues. It is, therefore, more than ever urgent that we do everything possible to eliminate every item of waste and cut operating costs to the bone. This brings us to one of the biggest problems in the industry.

Four weeks ago, in speaking before the annual meeting of the National Association of Shippers Advisory Boards in St. Louis, I urged leaders of the train-operating brotherhoods to join management in an all-out effort to modernize antiquated work practices. I pointed out then, as I have since, that featherbedding is a blight that hits the whole nation. It is all the more serious since labor costs eat up 52½ cents out of each railroad revenue dollar.

Unnecessary employment expenses of more than $500 million annually are inflicted on the industry—and the public—by old work rules that have remained largely unchanged for 40 years despite vast changes in rail operations. This waste, which adds about 10 percent to our payrolls, takes its toll in inflated prices, a weakened competitive position and reduced job opportunities in the industry. It is also a heavy factor in making railroading an almost profitless business, in freezing out new equity capital and in curtailing outlays for new plant and equipment.

I think railroad employees have a special stake in all measures aimed at increasing plant investment. Some labor spokesmen seem to have a chronic fear that automation and greater mechanization of operations will put men out of work. I would urge, however, that this fear be tempered with realization that only through heavy investment can the railroads hope to remain competitive with other carriers and stay in business. And if we go one step beyond, it is obvious that only through vastly increased investment can we hope to attract new traffic, expand, become a growth industry again and provide more jobs and better service for everyone.

With this necessity before us all, we hold out our hand to railroad employees to join management in creating a new climate of labor-management relations in this vital industry.

We ask for our workers' understanding and help in clearing away outmoded work rules and other obstacles on the track to greater operating efficiency and better service.

We *must* begin to realize to the fullest extent every possible economy that can be yielded by modernization, and we have no choice but to eliminate every kind of working rule that stands in the way. To do anything less can only add another shove to the railroads' downtrend. It could not be otherwise with an industry pressed to the wall by competitors whose rights-of-way are provided by government and which have other essential costs paid by public taxes.

Railroads can survive—and thrive—in this situation only by massive exploitation of their inherent advantages. These unmatched assets lie in our ability to move enormous volumes at diminishing costs and charges. No other carrier can approach the economy of rail transportation in this respect. Herein lies our competitive key to the future. We must give this ability maximum leeway and, in the face of subsidized competition, not simply rise to a comfortable peak of efficiency but go on beyond, exerting superhuman effort for results in the form of super service to the public.

Recent years—and certainly recent months—have seen a wonderful new spirit taking hold in railroading. Streamlined thinking is spearheading the way for streamlined operations. Railroads are stripping down for action. We are cutting out the deadwood of losing and unpatronized services and concentrating effort and resources in areas of greatest promise. Many traditional practices may have to go by the board in the process. A lot of sacred cows may have to be put out to pasture.

But there is no alternative.

Only through further drastic changes in operating methods and services can the greatest good result for all the nation. Only through drastic changes can we keep from being ground into extinction under the heels of government policies that subsidize and expand air, water and highway transportation with apparent wanton disregard of the effects on railroads and the million of people who work on, ship by, travel on, sell to and depend on railroads.

Perhaps there are grounds for hope that constructive public action may yet come on these basic governmental inequities. The people are with us. We need no further proof of this than last year's demonstration of popular demand for action by Washington, which led to passage of the Transportation Act of 1958 and repeal of the 3 percent excise tax on freight shipments. What we have witnessed in editorial support from newspapers throughout America and in the thousands of letters people wrote their Congressmen last year, is a clear signal of change in the decades-old attitude of the public toward railroad problems. I am convinced the American people are far ahead of their legislatures in seeing that the railroads long ago ceased to hold a transportation monopoly, that they are unfairly and senselessly victimized by government policies favoring their competitors, and that changes to put all carriers on an equal competitive footing are imperative. I say, the public be praised!

It would be unrealistic to assume that last year's actions managed to place railroads on anything like an equal competitive footing with other carriers. That legislation dealt with the top of the iceberg, and left the massive underlying inequities to be handled in a follow-up study and further legislation. This study, however, has yet to get underway.

It takes little study, I might add, to discern what is wrong with transportation today. Men take pride in achieving balance. But what pride can the nation take in the completely unbalanced development of transportation brought about by the present jumble of government policies? These have staged a boxing bout where the railroad contender has one arm bound by lop-sided regulation and crushing taxes, while the opposition has his gloves plastered with public subsidy. To top off the debacle, the crowd is stacked with government promotion specialists yelling for the other guy. It's a wonder railroads have even stayed on their feet!

The big transportation problem of today is not only that government helps provide air, water and highway facilities and services and energetically promotes competing carriers but that, in paying out vast subsidies for these purposes, it has depressed rate levels in all of transportation. Thus, the railroads, the carriers whose rates must cover *all* costs of doing business—including heavy taxes for the support of general government functions—are placed at a crippling disadvantage. Because of government air, water and highway subsidies, the nation is building up transportation capacity among the most expensive, wasteful and inefficient facilities. Being bypassed is the most economical all-purpose carrier available—the railroads.

The fight for survival in these circumstances poses awesome challenges for every railroadman. Here is a challenge for you engineers and operating men to turn up new cost-saving machines and new methods of doing more with less.

Here is a challenge to brotherhood leaders and our employees to help clear the way for full application of new devices and new methods.

Here is a challenge to passenger agents to find and secure a permanent niche for train travel in the national passenger transportation pattern.

Here is a challenge to freight traffic men to take a hard look at our rate structure

and to make rates and sell services on the basis of shipper needs and hard-headed economic demand.

And here is a challenge to top management to dig to the very heart of our complex social, political and economic environment and to make railroading a more-than-ever indispensable part of this intricate, ever-changing panorama.

As few other industries, railroads are intimately involved with the public and with public authorities of every type. Congress and state and local legislatures make laws affecting us. Courts at every level interpret these laws. All government units tax us. The Interstate Commerce Commission and state utility commission regulate us. Other agencies help handle our labor problems. And every day we deal in a multitude of ways with the ultimate boss of all the others—the American people.

What a challenge this position at the very heart of our economy poses for the railroad executive! Herein lie endless problems, as we know all too well—but there are also endless opportunities. Here are great opportunities to make the dynamism of progressive railroading felt in terms of progress and prosperity in all America, to make what we do reach out like ripples on a pond to touch everyone else.

This position also imposes special obligations. One can be expressed only in moral terms. It is the obligation that railroads, as one of America's first great industries, owe to our private enterprise system to remain free. Like it or not, we have become a primary test of the courage, perseverance and resiliency of private management. Though ill-conceived and misguided government policies do their utmost to undermine the railroads, we cannot break. Let us resolve here and now to hold the line. Railroadmen can make no greater contribution to America than to demonstrate in convincing terms an indomitable will to survive and succeed . . . regardless.

We must, therefore, continue to fight for basic changes in government policy that will more nearly equalize chances to compete for business.

We must continue to fight for legislation requiring commercial carriers to pay adequate user charges for their use of the tax-built and tax-free highways, waterways, airports and airways.

We must continue to fight for the right to diversify our business as other industries do—to accord railroads the same chance others have to provide services by truck, airplane and barge.

We must continue to fight for removal of that war-relic, the discriminatory federal excise tax of 10 percent on passenger tickets.

We must continue to fight for a lightening of the load of burdensome state and local taxes on railroad properties.

And, as I stressed earlier, we must somehow convince Washington to grant railroads more realistic tax treatment of investment funds spent for new plant and equipment. The average tax write-off period for railroad capital facilities is a wholly unrealistic 40 years. By contrast, investment in airplanes is depreciated over five years and the cost of heavy trucks is written off in seven years. Modernization of equipment thus comes far more readily to our competitors. This cannot be more strikingly demonstrated than by pointing out that today, when we have finished recovering through depreciation accruals the total investment in a freight car that originally cost $2,500, we must still find an additional $6,000 in order to buy a replacement, and to get that much we must earn $12,500 before taxes.

Inflated prices, low railroad earnings and an inability to attract equity capital—all these factors make tax-saving incentives urgent. Significantly, in 1955, the last year railroads were able to amortize defense-supporting investments over a five-year period,

they placed orders for 157,407 new freight cars. There is no reason why that feat could not be done again under similar stimulation. Imagine what this could mean to the nation's shippers and defense officials who worry over our capacity to meet emergency demands!

Finally, we must continue to fight for freedom to give maximum effect in our prices to the railroads' natural ability to move huge volumes at diminishing costs. Freedom for railroads to cut prices to the lowest practical level is intrinsically in the public interest. Certainly, people want the lowest prices they can get. And certainly, Washington wants to see every possible weapon utilized against the scourge of inflation and rising living costs. More freedom for railroads to cut transportation charges would prove a great aid in that battle.

This right to price competitively is of such supreme importance that I would like to underline it even at the risk of repetition. We must make a breakthrough in this area that will match the technological breakthrough yielding mass transportation at diminishing charges.

Shippers look at competitive carriers in terms of what each can offer in a combination of service and price, then decide which combination works out best in terms of the shippers' needs. Railroads have greatly speeded up line-haul transit time. And I am convinced we can perform some real miracles in pricing. We have really only begun to explore the possibilities in setting volume or incentive freight rates, "agreed" charges and other innovations in rate making. I think we will see much further progress in this area in the months ahead.

What is at stake may best be summarized by citing one financial analyst who noted ominously that the railroad share of intercity freight traffic has fallen from 75 percent in 1929 to about 45 percent today, and observed that railroads have yet to prove that they will—or even can—arrest this downtrend.

It is my firm conviction that railroads not only *can* stop this decline but can reverse it and enter a new era of expansion.

I know that railroadmen will not shrink from this contest, however bitter it may become, and that they will meet this test just as they meet the great transportation challenges of peace and war. And at the end of the line, we shall have secured our future; we shall have created a stripped-down, streamlined, space-age railroad system, offering exciting new levels of service to our dynamic country. [Applause]

President Meyers: Thank you very much, Mr. Loomis. We appreciate your taking the time from your busy schedule to come and talk to us today, and we are also pleased that you can attend our annual luncheon tomorrow. Through the work of this Association we are making every effort to solve the problems of the railroads, not only in our specific field, but in any other way we can be helpful.

As regards the problems ahead with respect to management–labor relations, we are sure that, as the result of your long experience in this field, the case of management and the over-all welfare of the railroads and their employees are in good hands.

Introduction of Paul Jones

President Meyers: There is one ever-present, all-important problem on the railroads which has not been mentioned directly as yet this morning, and that's the matter of safety. We have nothing in the program of any of our technical sessions dealing with safety as such, nor have we had a safety feature on our convention program for a number of years.

There is a reason for this—and it is not that our Association does not recognize the importance of safety, but rather that safety matters within the AAR, of which we are a part, are centered in the Safety Section of that Association—and I expect we have leaned over backward so as not to intrude on that Section's field of activity.

But having the feeling that this attitude left something to be desired out of the program for this convention, I determined to correct it. As a result, we have as our guest speaker a man whom, I expect, knows as much about safety as anyone in the country—the Director of Public Information for the National Safety Council, Mr. Paul Jones.

In this work, Mr. Jones lives and talks safety 365 days a year. He directs the steady flow of news and features on accident prevention and on the Council's acitvities to newspapers, magazines, radio, television and advertisers, and speaking of talking safety, it is said that since he came with the Safety Council in 1937, he has made more than 2000 talks or addresses on safety and human relations to a wide range of audiences throughout the United States and Canada.

I do not know how Mr. Jones will approach or handle his announced subject for this morning—"Give the High Ball to Safety" but whatever his approach or handling, I am sure he will give us a thought-provoking message. Without further comment, therefore, I would like to present to you Mr. Paul Jones, Director of Public Information, National Safety Council. Mr. Jones.

Give the "High Ball" to Safety

By Paul Jones

Director of Public Information, National Safety Council

Thank you very much, Bernie Meyers. This is a very informal interlude for you folks this morning. You are concerned here with your own problems, and it's gratifying to me in sort of a sadistic way to notice that you have problems, too, in your business because sometimes we get the idea over at the National Safety Council that we have a monopoly on headaches and things we have to meet. But after listening to Mr. Loomis' talk here, I see that you have some things too, and since we work in such close cooperation with you, in partnership, I would like to take just a few moments of your time. I do appreciate the opportunity.

As a matter of fact, we have to use sneaky ways to get into a meeting like this. If we let nature take its course, we are greeted on all sides with enthusiastic apathy wherever we make what we regard as a very simple and probably logical request. All we are asking you to do is not kill yourself. That sounds sensible when you first regard it, but we have managed over the years to endow it with such a stuffy, pontifical, dreary, unsaleable, repulsive approach that people think we are trying to sell them something fast and hidden when we are probably not only the dullest but the purest organization in the world. We sell nothing but safety. We are strictly non-everything—nonpolitical, nonsecetarian, nonprofit. We didn't plan it that way. It just came about that way in recent years. We are noninteresting, and I think we are nonacceptable in the highest circles because we have tried so hard.

Last night, I had the privilege of talking to your Board of Directors, your Arrangements Committee and your distinguished guests. Incidentally, I asked them to forgive me if I repeated some things today that I said last night. Just like in a broken-down juke box, it doesn't matter which button you punch, the same tune pops out anyway.

If I repeat, forgive me. The gentlemen on the left I think were the ones that were there last night. It is only when you get to be my age—and as my wife lovingly points out, I couldn't be dangerous if I tried—it is only then that your thoughts turn to safety.

I was telling these gentlemen last night that out in Iowa, for example, to show you the vulnerability of our movement, we have a chapter which has the enchanting title, "Life Begins at 80."

Now this may be handy to distinguish the chapter out there from the Youth Achievement Movement, but it is hardly conducive to bringing people into an exciting way of life for safety. The other day the president of the chapter came into our office. He said, "You know, we did something very remarkable which is a distinct departure from anything we have ever done."

We said, "What did you do?"

He said, "We admitted to membership in our organization two people who were only 78 years old."

I said, "How in the world did you ever take a chance like that?" He said, "A sizeable part of our membership felt we needed young blood." [Laughter] So I think that is the way it is with us.

We certainly need a shot in the arm, and we need it through such people as you.

Now I have been with the National Safety Council, as Bernie told you, for 20 years. He forgot to tell you that I came there out of grade school. I have been there for 20 years, so you would expect to find me in my own home where I am so highly loved and respected, but I never get there. I am out on the road making talks. That is an easy way to get along with the little woman. Never show up, and she will love you for it.

I don't know how it is with you fellows here this morning, but what I say in my home goes. I don't know where it goes. It must go somewhere.

My wife does precisely what I tell her to do. I said to her, "Dear, would you mind running the car into the garage?" And she did. [Laughter]

Now, when I have that kind of control over my family, then you would expect to find in my home a perfect example of safety. Yet the other night in my own kitchen I walked into a towel rack that had been placed by my wife at precisely eye level, and as I lovingly removed it from the wall, I discussed it with the little woman. Because I am a safety expert, of course, I immediately knew what to do. I merely moved it down two inches. The next time it poked her in the eye. [Laughter]

Unless you are safety men, you don't know those things. When I am home and want to go down to the basement and poke up the fire, there is a pair of bedroom slippers that I can slip into. All I do is open the basement door, step into a pair of buckets, and down I go!

Now, that is in the home of a man who makes his living out of this racket—out of this business. I can't even sell my wife on it, so how do you expect me to sell the public?

We resort to all sorts of snide, sneaky approaches, and the main thing we find in safety, which is one of the biggest headaches—if you think you have competition, what have we got?—is that more people are getting killed than we can enlist. What do we do? We blame it on the kids, the teen-agers; there is our trouble. We know that isn't true. Nevertheless, we do it. There is one small segment of safety where I can speak with some slight vestige of authority, looking as sick and confused as I do. I am sickly and confused and the reason I am that way is that I am the father of an 18-year old boy. I want to take a minute to brag about the kid, because he is smart. He is

only 18 years old and is a freshman in college, and already that kid knows more than his old man. He knows his old man doesn't know a darn thing. Now I was a junior in college before I found that out—before I knew my old man didn't know a darn thing—so that shows you how much smarter this kid is than I was.

He is a good boy. He is very thoughtful. He writes his mother and me every week or so. Even if it's for a few bucks, we hear from him. When the car is out of gas and he is out of a date, he never forgets his mother and me. He turns the car over to us to fill the tank. It's a swell car—twin mufflers, twin parking lights, twin sparking lights, twin floor lights, twin spotlights, everything's twins on the thing. He has even got a cord on the steering wheel. When you pull it, it plays "How Dry I am."

When I have a hard day, I do what any good American father does, I take it out on the kid. I say, "Look, it's you fool teen-age kids who pile up this big traffic toll. What do you do? You get an old, worn-out, unsafe jalopy. You paste wisecracks all over it. You open the muffler, fill it full of pretty girls and down the road you go." And there he knows he has got me. He knows I have the same ideas he has, but I can't get the women. [Laughter] So it doesn't do any good to hand the malarky to the teen-age kids or the adults or you folks at all.

This safety business for you and me and everybody either adds up to good business and good citizenship and common sense, or it's not worth a hoot. Nobody can prevent you or anybody else from having the darnedest accident in your life if you want to have it. You can build foolproof highways, foolproof grade crossings. You folks know this only too well. You can build foolproof cars, but unless you build something foolproof in the mind of the driver, which is the only real safety device, you haven't got it made at all. That is the reason we talk about attitudes and people.

I have a simple idea as to how we can wipe out all the accidents, but I can't get anybody to bite. It is a simple thing. I want to change human nature. That's all. It's just as simple as that, but on the premise that it may be a little difficult to do this overnight, I will settle for just changing some of the baser elements of human nature, elements that cause wars, that cause accidents, that cause you people the problems you have today, that cause us the problems we face today—such human attributes as greed and avarice, and belligerance and impatience, and a great, insane desire for speed wherever you go, to get there first, ahead of everybody else and nuts to the other guy, for the disregard of the rights of others, for the disdain, for failure to recognize the rights of others, which I think is one of the most important things that we are up against today. We are certainly threatened with it in the safety movement.

I told the gentlemen last night that in our attitude toward the public it very often strikes me that we have the same great interest in what we are doing as the little kid who lives around the corner from me in Winnetka. The 8-year-old kid came home with one of the most beautiful shiners I have ever seen in my life. He said, "The O'Reilly kids hung this on me." His mother said, "What did you do?" He said, "All I did was make fun of the Pope."

She said, "You made fun of the Pope to the O'Reilly kids? Didn't you know they were Catholics?" He said, "Oh, I knew the O'Reilly kids were Catholics all right, but I didn't know the Pope was." [Laughter]

We go about this business with the same thing we are always asking. We are jealous of the foreign cars now. We are asked constantly, "What do you folks at the National Safety Council think about the small foreign cars?" We have a simple answer. They have one great big advantage over the American cars: There is more room on the outside.

It isn't what you drive. It isn't how fast you go, but the kind of life you live, and if you believe sincerely that you want to put everything into your business that you can.

I ask from you today the greatest degree of activity and sincerity that you can give.

I always envy you folks or any engineers, especially in your business, where thank heavens you can lay out something in your work that I can follow, namely, a railroad track. I can see that. I know where the two rails are going, although I have to trust the conductor and the engineer. We depend on you the same way for safety.

My wife and I spent half our vacation in Pennsylvania two years ago trying to get off the Turnpike. The engineering techniques of getting us off the clover-leafs were too much for me, and we ran around and around until we got dizzy. We never could have gotten off if we hadn't bumped against a maintenance truck for the highway which escorted us. That's the only way we got off the thing.

You know, when my wife and I drive, we practice what we preach. We each take 50 miles and then turn the wheel over to the other one. It gives the driver a chance to recuperate from the experience he has had with the other driver.

Before I close I want to thank you people for the wonderful condition that you are in this morning. I appreciate the reception you have given us. I did notice when Mr. Loomis spoke you stood up, and when I was introduced you sank back, but that's expected with safety [laughter] because we, as I say, have a very unpalatable subject. But you know we have a conference every year of the National Safety Conference. We draw 14,000 people from all over the world. We tell the happy delegates it isn't only for the formal education you get from the great speakers, but the quieter chats in which you engage and the research you do in Chicago while you are here.

Last October three of the boys went out and did some researching. They found out what all of you know. They went to catch a train to go home. When they got down there the train was not quite ready. Some repairs had to be made. The next thing they knew the train was leaving and two of these characters tore down the track after it. One grabbed a railing and the other one caught the rear coach. The third one, running after it, missed and fell flat on his back. He got up, dusted himself off and with great dignity walked back to the station.

The stationmaster had taken all this in. He walked up to the fellow and said, "Sir, I want to compliment you upon the greatest demonstration of philosophical resignation I have ever seen in my life. The average guy would have flipped his lid if that had happened to him, but you, sir, took it like the great sport you are."

The fellow said, "It struck me as kind of funny because the two guys who caught the train had come down to see me off." [Laughter] I hope nothing like that happens to you this morning.

I would like to close by expressing to you the gratitude of the National Safety Council for the close alliance we have enjoyed over all the years since we were founded by the railroad industry. As I said to these gentlemen last night, if we liked you for no other reason, we would like you very much because you folks have had the stupidity—I guess that is the best word for it—to carry on the insidious slogan "Safety First" which was going great guns for us until a psychologist came along and said it was wrong. If you believed in safety first, you didn't believe in scientific development, in scientific research, in progress. To that I have a very simple expression—nuts. "Safety First" was the greatest safety slogan we have ever had. They tried to kill it for 25 years. It won't die. They tried to get something to take its place. It won't be born, so more power to you. I hope you keep on using it.

We are utilizing science in our work now, and it is a great thing. It is called motivation research. I am in that field. That is where they go out and find out what you should do that you are already doing, and know you should do, and they will charge the client for finding out if you are doing it.

A great Eastern university is an example. They have completed a four-and-a-half-year research project, and have determined that parenthood is hereditary. I am very much intrigued with that. I have given it a lot of thought. As nearly as I can figure out, it means if your parents didn't have any children, then chances are you won't have any either. [Laughter]

So we are utilizing all these great developments of science, and we certainly want to cash in on all we can, because very obviously what we have been doing hasn't been working too well. So I ask that your help and the help of groups just such as this and the leadership and support that industry over the years has given safety, be extended just a little bit. You have every selfish reason in the world and every humanitarian reason for going all out for safety. Your own employee record is excellent. We conduct this contest, of course, every year with you folks, and it's amazing to see how that rate has gone down in employee safety on American railroads.

Then you have this grade crossing problem. I don't know what it is that gets into the minds of the average motorists. You see how they behave. Confidentially, I think I am the only guy that drives a car today that drives exactly right. I have only one dissent from that—my wife. She thinks I'm the biggest jerk that every got behind the wheel.

I know the average driver, he and he alone is the answer to the Lord's Prayer. In view of that I hope that we all try to improve our driving performance as much as we do anything else, but one of the little idiosyncrasies that we have when we are behind the wheel is that there is a certain percentage of us that likes to chase trains. Any fool knows when you come to a thing marked "railroad tracks" with crossbars, bells ringing and dancing girls and everything else to tell you here is a train track, then the supposition is that sometime or another a train is going to come along. These guys not only don't pay attention to that, but if they see a train come along, they accept it as a personal challenge, and away they go, and the race ends up in a tie too often, and you know who is going to win that one. Then our railroads are faced with another accident. In a great many cases you couldn't influence these characters. How often do you pick up a paper and read where a fellow has driven past the gates, past a waiting line of cars into the path of a train so he could save two minutes. Instead he was knocked out for enternity.

That's a bad investment. Any bookie will give you better odds than that. Yet, that is what you are up against, so you have every reason and every cause to be on our side of safety, and I know you are.

It is a very frustrating business just as yours is, but we come very close at moments to realizing the ideals for which you and we and all of us are striving in safety.

I would like to close by giving you a case history. Before I came to the National Safety Council I was a newspaperman in Cleveland, Ohio, and I was sent out to cover a traffic accident. When I got there the photographer and I saw at a glance it was too late for us to do anything. It was too late for anyone because stretched out on the pavement there in front of us was the very quiet form of a 6-year-old boy. This youngster had been playing ball in the yard of his home, and he did what comes naturally for any kid. He had followed the ball into the street, into the path of a car driven by a man who would rather die than harm a hair on the head of that boy.

Yet, when we got there, there he lay, covered over with a grapevine of a neighbor until the coroner could get there.

The youngster had been wearing tennis shoes. His shoes had been knocked off his feet. At that time, I thought I was a pretty hard-boiled newspaperman. When I got home that night I went up to the bedroom and looked down at the face of my own boy, and I was struck by how this kid of mine looked like the boy I had just left on the street. I thought of the dreams and hopes and aspirations that my wife and I had for our youngster. I knew his father and mother had the same hopes and dreams. I couldn't get out of my mind the look on the face of the boy's mother or on his father, and most of all, on the man who had driven that car, whom I am sure at that time never wanted to see an automobile as long as he lived.

I remember for a couple of days we had been rough on our boy because he had been tracking mud in with his tennis shoes. I couldn't get the tennis shoes lying beside the boy's body out of my mind. Never again would he track mud in anybody's home, nor would there be the twinkling of an eye. The whole home had been changed by that tragedy that could have been prevented.

I prayed to the good Lord that night that a tragedy like that would never visit our home, and I prayed, too, that the good Lord would give me enough sense from that day on when I got behind the wheel of a car or worked at my job or when I was in my own home that I would share and share alike with the people with whom I came in contact on the highway or in my home or my working conditions or any place else, and that I would dedicate myself to living the most sensible, careful, decent, courteous Christian life I could because I believe that religion can be applied nowhere more effectively than behind the wheel of an automobile or on your job or in your home in these trying days.

I believe if all of us would go home and examine our conscience and ask ourselves what we can do even more than we have been doing to make things safer for the people with whom we associate, and work, and share the highway, it would be a richly rewarding experience for all of us. For each in our own way to do that would be building a bridge to a happier, safer, better way of life for those youngsters whose footsteps must follow ours.

An old man traveling along a highway
Needs came at the evening cold and gray
To a chasm—vast and deep and wide.

The old man crossed in the twilight dim,
The sullen stream held no terror for him.
But he turned, when safe on the other side,
And built a bridge to span the tide.

The old man said to a fellow traveler near,
"You're wasting your strength building here.
You never again will pass this way.
You've crossed the chasm deep and wide.
Why build a bridge to span the tide?"

The builder lifted his tired, gray head.
"Good friend, in the past, I've come," he said,
"There follows after me today a youth,
A youth whose feet must pass this way.

"This chasm which has been as naught to me,
To that carefree youth may a pitfall be.
He, too, must cross in the twilight dim.
Good friend, I'm building this bridge for him."

Thank you very much. [Applause]

PRESIDENT MEYERS: Thank you very much, Mr. Jones. You have certainly fulfilled my desire to feature safety at our convention. You have done so very well. We appreciate very much your addressing us this morning. I can assure you that your message has not fallen on deaf ears, and that it will stimulate all of us to a greater safety consciousness in everything we do both on and off the job. Thank you again.

Presentation of Honorary Membership Certificate

PRESIDENT MEYERS: On February 19, this Association bestowed its highest honor—that of Honorary Member—on another of its members. This honor, under the Constitution of the Association, is reserved for those persons of acknowledged eminence in railway engineering or management, who are proposed for Honorary Membership by ten or more members of the Association and who are elected by a unanimous affirmative vote of the Board of Direction. The number of Honorary Members of the Association is limited to ten.

Presently, the Association has seven living Honorary Members.

Today we are pleased and proud to add another name to this list—that of Dr. Lewis K. Sillcox, honorary vice chairman of the board of the New York Air Brake Company. If Dr. Sillcox will come to the platform, I would like to present him with a Certificate of Honorary Membership.

[Dr. Sillcox came forward.]

Dr. Sillcox, I congratulate you upon your election as honorary Member of this Association. Before presenting you with your certificate, I would briefly like to say a few things about you—briefly, because to tell of all of your many achievements and contributions to the railroads would be utterly impossible in the limited time permitted during this Opening Session.

Dr. Sillcox became honorary vice president of the Board of the New York Air Brake Company in 1953, having joined the company in 1927 as first vice president. Before then he was a railroad man, serving as mechanical engineer on the Illinois Central from 1916 to 1918 and as general superintendent of motive power, Chicago, Milwaukee, St. Paul & Pacific Railroad from 1918 to 1927.

Dr. Sillcox is a Life Member of the AREA, having been a member since 1920. Since 1921 he has been an outstanding member of Committee 16—Economics of Railway Location and Operation. He has given generously of his time, vigor, knowledge and ability not only to this Association but also to many other engineering and railway associations. Among these are the American Society of Mechanical Engineers, of which he is a past president and an honorary member; the American Society of Civil Engineers; the Western Society of Engineers; the American Institute of Mining and Metallurgical Engineers; the American Institute of Chemical Engineers, of which he is also an honorary member; the Newcomen Society of England; the American Institute of Electrical Engineers; and the Engineering Institute of Canada, another association

of which he is an honorary member. His leadership as engineer, railroader, administrator, educator, citizen and layman is widely recognized.

Dr. Sillcox, in view of the honor which has been conferred upon you in your election as an Honorary Member of this Association, I am pleased to present you with this framed certificate indicating Honorary Membership and bearing the following words: "For his many learned contributions to the work of this Association, and for his outstanding service to the railroad industry and the engineering profession."

[President Meyers presented the Certificate to Dr. Sillcox and the assembly applauded.]

Dr. Sillcox: I don't know how to thank you sufficiently. I will call upon an experience in connection with my son when he left the Navy when they tried to have him remain in the Navy and they said to him, "If you stay here with a wife such as you have, you will end up as an admiral."

Now here I am with friends such as I have, ending up as an Honorary Member. I owe it all to you, and I will try for the rest of my days to justify your confidence in me. Thank you. [Applause]

President Meyers: Our next speaker needs no introduction to you, having been your president a year ago and the presiding officer at our 1958 convention. I refer to Mr. Ray McBrian, director of research of the Denver & Rio Grande Western Railroad, whose trip to Europe last fall took him to Italy, Switzerland, Germany, France, Belgium, Holland and England. In connection with that trip, the Board appointed Mr. McBrian official good-will emissary of the AREA, and he was given an official letter of greetings to present to the officers of the railroads he visited.

Mr. McBrian I will be pleased if you will come to the podium and tell us—"What you Observed in Europe of Interest to the American Railroads". Mr. McBrian.

What I Observed in Europe of Interest to the American Railroads

By Ray McBrian

Director of Research, Denver & Rio Grande Western

Mr. Meyers, ladies and gentlemen: The observations I made during my trip to Europe last fall were of activities in Italy, Switzerland, Germany, France, Holland, Belgium and England. My trip lasted two months. The purpose of my trip was to seek new ideas in research fields on the railroads and related industries. I was fortunate also that the AREA gave me letters to the effect that I was an ambassador representing AREA officially. I might tell you that your AREA is most highly regarded. Your standards are almost a bible in the world railroad field, and the various bulletins and transactions are reviewed and studied with great interest.

One important fact of which I am convinced is that we should improve our relations with European railroad people by encouraging them to visit and partake in such activities as this annual AREA meeting, possibly by reciprocating arrangements. Such I believe could be arranged for through Government agencies such as the State Department. Their value in the exchange of information and new ideas will be great.

The over-all observations that impressed me most were first the scope of the field of research and the intense applications of the results being made by the railroads and allied industries. (I would like to say here that the railroads of Europe are nationalized. There is one thing that cannot be done, and that is reduce labor. They have to keep

people employed, but in the development of mechanical improvements or other research, in my observation the sky was the limit.) Second were the overwhelming determination of these people to produce quality products, their intense desire to work for their country and to serve world markets. This meant the realization that "American labor" is pricing itself out of the market in our country and in world markets, through its continuing demands for higher wages, featherbedding and other demands that send prices skyward. In many of our railroad products fields, these European countries can now produce better quality products at less cost than those of our manufacture—and we should begin to think about such European products as rails, locomotives, steel products, etc., being offered our industry.

It would like to repeat that in most of the countries I visited in Europe the quality of workmanship is excellent, and everywhere they are working to improve the quality, expand their markets, increase the prestige of their countries so that they may successfully compete and invade world markets, including our country, where the continuing spiraling of costs invites them to take over.

Some specific observations might be of interest. In Switzerland, diesel-electric and proposed diesel-hydraulic locomotives are being introduced on the Swiss National Railroad. This is due to the increasing shortage of water-power developments for electrical power. Atomic energy is being considered for power and heating. One large railroad energy supplier has established an atomic energy department.

These people have been diesel manufacturers for many years. They plan studies for atomic power units in any possible field—whether generating plants, or transportation units, both marine and land. One study and actual application is that of a combined nuclear heating plant and a power plant of a 30-Mega watts thermal output to be used both for heating a special district and supplying electrical power at the same time. The complete nuclear heating and power station is to be situated in two underground rock chambers producing 6000 kw electric power. Such stationary electric generating and heating plants are also of interest to American railroads because they offer possibilities of an economical division of atomic energy uses and costs wherein both heat and electrical power could be developed. In England I found that studies were being made by one of the large turbine manufacturers to develop atomic-powered turbines. This, while primarily for marine use, could also be applicable to railroad transportation.

I found a translation of a technical article which described research programs being carried out at the Bauman Institute, Moscow. It read in part: "The steam locomotive which has produced a revolution in transportation, has already served mankind faithfully for 120 years, has largely been and is now being supplanted by incomparably more economical and more powerful diesel, gas turbine and electric locomotives. However, in the near future it is possible that these locomotives may also relinquish their place to a more advanced type. Atomic locomotive designs are being developed with a view towards using this type of engine application in Russia at the earliest opportunity."

One design application considered in Russia is for an atomic steam turbine of 5500 hp capacity. Another design is of a different constructural type steam turbine. Both would be enclosed by a biological shield. In another imaginative type it is proposed to use helium instead of steam as a working fluid. Hot helium would drive turbines, and the turbine through hydro-mechanical means or hydraulic drives wouyld set the wheel axles in rotation.

The reasons given for such developments are that atomic locomotives will conserve fuel and eliminate the need for building and maintaining vast stores of fuel. The number of water supply stations can be reduced to about one-tenth. The number of personnel

required for servicing and repairing locomotives would be cut in half. They will permit increasing the traffic capacity of main line railroads by 50–70 percent. It is difficult to overestimate the significance of this type of locomotive for their country. The length of railroad lines in the Soviet Union is three times the length of the equator, and from the standpoint of railroad freight traffic the U.S.S.R. "occupies first place in the world."

I mention these plans for use of atomic energy in Europe because at some future date we also on our railroads will be making such studies and engineering evaluations.

In Germany the railroad is increasing its studies into technological research and developments. The use of long welded rails, using flash welding, is most successful. Millions of concrete ties are being used yearly. The concrete ties to me were a revelation as to what might be done with concrete. They are so prestressed, and cured by steam heat that car and locomotive wheels when in contact with a tie because of derailment, only result in the tie being chipped and not shattered. The cost of such a tie was equivalent to $4.50 American money, and advantages claimed were long life, 30 years, and material reduction in cost of track maintenance.

Off-track work equipment of unique designs were developed and are under development. Panel-type track construction was seemingly being utilized most successfully. Railroad operations are being developed with containers, and piggyback service of loaded trucks, etc., on special-design flat cars is being offered.

Dieselization is proceeding at a very fast rate; the diesel hydraulic locomotive is the standard in Germany and is becoming standard elsewhere. Preference for this type is on the grounds of less wear and tear on track structures, and cheaper maintenance with equal or greater efficiency and less first costs. The German State Railroads control and specify the constructional design of the locomotive so that all locomotives built have the same appearance and size, and parts can be interchanged because of standardized construction design features. They permit any number of builders to bid on different designs of engines, transmissions, etc. All such parts are interchangeable, which makes for greater economy in manufacture. It was this type of research and standardization ideas which impressed me greatly, in that it permits freedom to develop and place such projects into actual usage but does develop a trend into standardization which does not stifle research and inventiveness. For example, if applied in rail design, such standardization would only include constructional dimensions, such as width of base, bolt hole spacing, fishing height, but would permit freedom for any special design features or variation of weights or sections whereby utilization could be made practically of any research ideas.

One other important fact to me was that the German State Railroads, which have 265,000 freight cars, have now 100,000 of these equipped with roller bearings—and plan within the next few years to have all so equipped. They told me there was no other answer to solving the hot box and the "burnt off" journal problem.

Approximately, it was costing them 8 percent of total freight car costs to equip the cars with roller bearings.

Research is a "must" project and is being fully explored by the individual railroads of Europe and also by the Railroad International European organization.

I visited several European industrial railroad suppliers' research organizations and I was impressed with the scope of their studies and the possibilities which such studies might have for our railroads also.

Such fields included fuel, corrosion studies, use of air films for lubrication instead of conventional lubricating oils and greases. Their developments in the fields of electronics, electron microscopes, use of ultrasonics for inspection, etc., were far advanced.

Inexpensive, low-cost anti-slip devices which eliminated sanding on the Swiss Railroads, and special types of rubber seals withstanding service oxidation conditions were of special interest. Such are only some examples of the progress observed and I hope this will give you a brief picture of the observations which I made during the stay in Europe. Thank you. [Applause]

PRESIDENT MEYERS: Thank you, Mr. McBrian.

Since most of us aren't as fortunate as you in being assigned to a trip to Europe, we particularly appreciate your telling us about these interesting railroad and allied developments which you have observed.

As all of you know from statements in the AREA News and other sources of information—and as many of you know from participation therein—this hotel, on Friday and Saturday of last week was the scene of a conference of railroad officers and key federal and state highway authorities on railroad–highway problems—problems relating to construction, maintenance, insurance and other aspects of railroad-highway grade crossing elimination and protection—arising out of the huge federal construction program under way in the United States and in prospect for the next five or more years. One of the key figures in arranging for that conference, which was sponsored by the AAR Committee on Grade Crossings, was introduced to you earlier, but I want to present him to you now to tell us something about the conference for the benefit of our members who could not be in attendance. I refer to Mr. Hal H. Hale, assistant to vice president–highway transportation, AAR. Mr. Hale is a civil engineering graduate of the University of Tennessee, and to mention only a few of the many positions of responsibility he has held, he was connected with the City Engineer's office of Knoxville, Tenn., for 12 years, from July 1926 to August 1938, starting as a designer, and becoming city engineer of Knoxville in August 1933. From August 1938 to November 1941, he was office engineer, Atlantic District, Portland Cement Association. At the latter date he became assistant to secretary and Washington representative of the American Society of Civil Engineers, following which from January 1, 1944, to January 1, 1955, he was executive secretary of the American Association of State Highway Officials at Washington, D. C. On the latter date he came to the Association of American Railroads as assistant to vice president—highway transportation, in which position he has been the chief contact man of the AAR with the federal and state highway officials and with the individual railroads regarding highway matters; with the Bureau of Public Roads; the Highway Research Board of the National Academy of Sciences; the AASHO; and all other agencies involved in state and federal highway construction—especially with regard to railroad–highway grade crossing separation, elimination and protection.

Mr. Hale, who as I have said earlier, was one of the key figures in arranging last week's conference on Railroad–Highway Problems, has consented to tell us something about the conference and to summarize the discussions which took place. I am pleased to present to you Mr. Hal H. Hale, assistant to vice president—highway transportation, AAR. Mr. Hale. [Applause]

Summary of Discussions Before Industry Conference on Railway–Highway Problems

By H. H. Hale

Assistant to Vice President—Highway Transportation, AAR

President Meyers, special guests, members of the AREA:

First I would like to express to you the thanks and appreciation of the Committee on Grade Crossings of the Association of American Railroads for inviting me here to speak for them today and give you a brief report on the conference held on Friday and Saturday. We are very grateful for your courtesy.

A friend of mine from England a few years ago told me the minister of his church in London made the comment that he was never bothered when he saw the members of his congregation look at their watches, but if they held them up to their ear like this, he got a little disturbed. The hour is growing late, so I will try to make my report rather quickly.

I am speaking from notes and I will try to give you some of the highlights of our meeting. The conference on railroad–highway problems, I believe, was the first of its kind to be held in the industry. We had a large representation of top officials, engineering, legal and others, present. As President Meyers has told you, we had top highway officials, both federal and state, attending the conference and participating in our activities. It was one of the most attentive audiences I have ever seen. I believe in the two days' time I saw not more than a half-dozen men leave the room during the various sessions. That is a tribute to the quality of the conference. It has been said on many occasions that the mind can absorb only as much as the seat can endure. Some of those seats got rather hard.

The Committee on Grade Crossings of the Association of American Railroads is composed of 13 members. Twelve are top engineering officials of 12 member lines. The American Short Line Railroad Association is represented by an ex officio member. The committee was organized in the middle 30's and was authorized and instructed by the Board to handle problems of a national character with state and federal highway officials particularly with regard to highway crossing separations and protective devices.

In order to give you some indication of just what lies ahead for our industry in this greatly expanded highway program, we asked the 12 members of our committee to canvass the situation on their respective lines with regard to the number of crossing separations that were now under construction on those lines, the number that were now in the negotiating stage, the number of protective installations that were now under construction, and the number under negotiation. We felt that would give a sampling of just what the problem is with regard to this very difficult situation. The survey showed that on those 12 lines, which incidentally operate in 44 of the 49 states, there were presently under construction 333 grade separation projects. There are 765 in the negotiating stage. That means that there are almost 1100 projects in the active stage. Some of these projects are going to cost six, eight, and ten million dollars apiece, but on a conservative estimate of $500,000 each, that means that those projects now active will cost something approaching 550 million dollars. Now before anybody gets apoplexy I would like to say this doesn't mean the railroads are going to be called on to lay out that much money; but they are going to be called on to lay out substantial sums.

In the protective device category the 12 lines now have 110 protective device installations under construction and 194 under negotiation. This represents only the activity in the first two and a half years of a 13-year Federal Aid Highway Program.

If that doesn't sound big enough, I would like to call your attention to the fact that it is estimated by responsible authorities that in the next ten years all levels of government—federal, state and local—will spend for highway design, construction, maintenance and operation something in excess of 100 billion dollars.

Now to get to the conference itself. The first morning we had a panel discussion on the New Bureau of Public Roads Memorandum 21–10. Any of you who haven't heard of that memorandum certainly will before too long. Memorandum 21–10 supersedes some 30-odd memoranda that have been issued over the past 30 years dealing with highway crossings and protection. It takes the place mainly of GAM–325 issued by the Bureau back in 1948.

Memorandum 21–10 is the Bureau's interpretative memorandum of two sections of the new Highway Code passed last year by the Congress called "Title 23, U. S. Code, Highways." Sections 120 and 130 are the two that deal with these particular problems. Again, the memorandum is an interpretative memorandum replacing all previous memoranda.

The AAR Grade Crossing Committee had negotiated with the Bureau of Public Roads on this new memorandum for some 18 months. It was released last October. In negotiating, please understand that we do not write the memoranda. We state our case to the Bureau of Public Roads. The Bureau has given us a very careful hearing. We did not get everything we asked for in 21–10, but we did get, in the opinion of the committee, substantially better consideration than we have had under previous memoranda.

I would like to give just one illustration of that. The statute provides that the railroads shall be assessed on the basis of "net benefits" that accure to them in the elimination of crossings, but that the assessment shall not exceed 10 percent. Under the old memorandum, if we had a 2-lane grade crossing that was to be replaced by an 8-lane separation it was possible in the opinion of the participants in the negotiations to rule that the railroad should be called upon to pay 10 percent of the cost of the new 8-lane separation. If I seem a little hoarse this morning, it is because we argued over that point quite some time during the 18 months. The new memorandum does not make such an interpretation. It rules that we would be assessed only for the estimated cost of eliminating the existing number of lanes. That is a very important interpretation.

I repeat that our AAR Committee does not have the power to write such memoranda. That power is vested in the Federal Roads Administrator, Mr. Bertram D. Talamy. It may be said that this procedure is not legal. When the Bureau issues such interpretative memoranda they are published in the Federal Register. It is considered to have the same effect as law. Until such time as appropriate courts might rule to the contrary PPM 21–10 is the document that covers all Federal Aid railroad–highway grade separation matters and protective devices.

On the panel we had four members, including the assistant commissioner of the Bureau of Public Roads under whose jurisdiction PPM 21–10 was developed. We had two chief engineers of our member roads, and the Colorado State Highway engineer who is a member of the executive committee of the American Association of State Highway officials. Those discussions on 21–10 were helpful. PPM 21–10 has been distributed to all member roads by our office in Washington. We have additional copies available upon your request.

The afternoon discussion on Friday had to do with protective liability insurance in connection with grade separations, and work adjacent to railroad properties. I had that baby in my lap when I was secretary of the highway officials, and when I came

with AAR in 1955, there he was again. We negotiated on the protective liability insurance question for over three years. The committee that did the negotiating for the AAR was a special committee authorized by the Board, composed of engineers, insurance department heads and attorneys. When you get the three professions together you have your hands full. Bless their hearts, we came out finally, after long negotiations involving highway officials, the Bureau of Public Roads, and Casualty and Mutual Underwriters with the new memoranda on protective liability insurance. Again, while we did not get everything we asked for in the negotiations, it is the opinion of the committee, and of our Board of AAR, and of the Highway Officials, and of the Bureau of Public Roads that we did get a substantial improvement over those types of documents that we have had in previous years. A new memorandum was released just before this conference last Friday by the Bureau of Public Roads officially interpretating the insurance form. You know, down in Washington you issue a memorandum. Then you issue a memorandum explaining that memorandum. Then you get a memorandum out explaining the first two. Then you issue a new document that purports to explain all of them.

The new memorandum is PPM 20–12. This will be sent to you just as quickly as we can get them out of the office this week.

On the Insurance panel we had two attorneys, Mr. Welch from AAR and Mr. Enfeld, the general counsel of the Bureau of Public Roads and one railroad engineer. The moderator of the panel was Mr. McHugh, insurance department head of the Chesapeake & Ohio.

A question period followed each of the panels. We did not get to answer all the questions presented to us for which we were sorry. I think I can assure you that two panel members from the Bureau of Public Roads were the men who got the most questions. In fact, I think there were not more than two or three questions directed to other panel members. The Bureau boys were under the gun and I take my hat off to them. They did an excellent job.

Another subject that we did not discuss as much as we wished was maintenance of structures. The problem of maintenance of grade separation structures and protective devices is growing in importance, and unfortunately most of that maintenance falls right on the pocketbook of the railroads. Sometimes there is a belief that this can be cleared up simply by going to the Bureau of Public Roads in Washington and taking it up with them. That is not the case. The matter of maintenance of these structures is one that has to be handled strictly at the state level. The Bureau of Public Roads has no authority, no power of any kind, to enforce or regulate, or direct these maintenance matters. So that, burdensome as it is, is a matter that falls primarily upon the state grade crossing chairmen and state grade crossing committees.

We have a grade-crossing committee in each state. They are very active and have done a lot of work in recent years in trying to solve some of our problems. The maintenance is not something that can be settled in Washington. It has to be settled at the state level.

Now if I can take just about two minutes, Mr. President, to talk about what lies ahead of us. One of the serious things that has grown out of this great road program, is the matter of limited access as it applies to the 41,000 miles of interstate system. We are negotiating with the Bureau officials on that. How long we will have to negotiate, I can't say, but I assure you our committee is working with them. We are trying to get a more liberal understanding of our problems as they are affected by this limited access, and I am sure that within a reasonable length of time we will get favorable

consideration on most of our problems from the Bureau of Public Roads. No state is going to violate the federal statutes on the limited access question in the absence of a memorandum from the Bureau of Public Roads outlining their views, so it has to start in Washington. We hope to have a solution before too long a time.

We are also negotiating with the Bureau on the memorandum PPM 30–3 which covers the force account work that you do for a highway department. That is going to be a long operation. It is a very complicated memorandum. We have called on member roads for information to help us explain the problem to the Bureau. It is a memorandum that has been in effect for a good many years. It needs to be brought up-to-date, and we are working on that just as rapidly as we can.

In January 1961 the Bureau of Public Roads will make two reports to the Congress. One is called the "Section 210 Study" of the Act of 1956. That is a cost analysis study, a report to the Congress on which the Congress may determine equitable tax procedures to finance the road program, to be assessed against highway users and other beneficiaries.

This report was supposed to have been made this March, but it was delayed primarily because it is tied in with the big AASHO road test. I believe you have a talk on the Road Test this afternoon. The Bureau must also report to the Congress on recommended standards for the sizes and weights of motor vehicles. I think I need not dwell on either of those reports at length because I am sure that you appreciate what the contents of those reports mean to the future of our industry.

We are in constant contact with the Bureau officials on these reports, and we have submitted our views to them at their request. We have official observers on the Illinois road test. We are trying to keep our finger on these things just as closely as we can, I assure you that the Committee on Grade Crossings will do everything within their power to protect the interest of this industry.

Now in closing, Mr. President, I would like to be a little bold, maybe a little presumptuous. We can't turn the clock back in the situation that confronts us in the highway field and in our competitive problems. The clock cannot be turned back. I think the interests of our industry can be best protected and improved by close contact and understanding relations with the various state highway departments with which we have to deal. These men in the highway departments are human. They are engineers. I know. I have worked with them for years. They get in their pants just like we do. They like to be understood, and they have problems. I think most of them want to understand ours, so anything I can say to encourage our industry to work closely and continuously and cooperatively with these highway officials, I am sure, will accrue to our best interest in the long run. It will be a far better position than backing ourselves in a corner, so to speak, and daring somebody to knock a chip off our shoulder. You know when you get back in a corner there is only one way out—that is the same way you went in. By cooperation, by working together and getting them to understand our problems, solutions are often simple.

When the question of off-track maintenance equipment was raised highway engineers didn't know what we were talking about. It was very foreign to them. They understand what it is now. I think I can say sincerely that most of them want to be fair and want to treat us fairly, within the statutes they have to work under.

Mr. President, I hope I have been able to give you some sort of a picture of what the situation is, as I see it. I would like to say that we in the Washington office, Mr. Hollar, Mr. Feldman and I, are ready and willing to do anything that we can to be of assistance. We don't know all the answers. Thank you very much. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Hale very much for summarizing this conference for us. Having attended the conference both days I can testify that it was a very worthwhile meeting, I hope in the future that we can have similar meetings from time to time to bring the railroad engineers face to face with the top officials of the Bureau and the AASHO. Mr. Hale, I congratulate you upon your important part in arranging the conference and thank you again for summarizing its discussions for us this morning.

Gentlemen: This completes the program of our Opening Session. I am sure you have both enjoyed and profited by it. I would like to point out that eight of our committees have scheduled luncheons for this noon. As soon as this meeting is closed, I think you should go directly to your luncheons so we can reconvene here promptly at 2 pm.

The first report at our afternoon session will be that of Committee 9—Highways. The feature of that committee presentation will be a talk by W. N. Carey, Jr., chief engineer for research on the AASHO road tests being carried out at Ottawa, Ill.

The meeting now stands recessed until 2 pm.

[The meeting recessed at 12 o'clock noon.]

Afternoon Session—March 9, 1959

[The meeting reconvened at 2:00 pm, President Meyers presiding.]

PRESIDENT MEYERS: Will the meeting please come to order.

You will note that we have adopted a double, two-level speaker's table for this afternoon's session in order to provide enough places for our large committees without the necessity of stretching out one speaker's table to the ends of the room, which would be most undesirable both from your standpoint and that of our committees.

We have a number of important committee presentations to consider this afternoon, three of them with special features, and it is going to be important that we keep moving right along with a minimum of lost motion if we are going to keep on time.

With this in mind, may I ask that the chairman, vice-chairman, secretary and all subcommittee chairmen—especially those to present reports—take places at the main speaker's table, and that all of the other members of the committees find places at the lower speaker's table, and then fill out as may be necessary any seats that may be vacant at the upper speaker's table. This will shorten the time required for subcommittee chairmen to come to the podium to present their reports. While the time saved by individual subcommittee chairmen may not amount to much, the total saving throughout the convention will mean quite a little bit.

As another time-saving expedient, and incidentally, to save wear and tear on the committee chairmen in repeatedly coming to the podium to introduce the various subcommittee chairmen, we have this year provided the chairman with a microphone at his place at the speaker's table so that he can make such introductions and comments as he desires from his place without the necessity of coming to the podium each time.

Discussion on Highways

[For report see pp. 245–258]

[President Meyers presiding.]

PRESIDENT MEYERS: The first report on our program this afternoon is that of Committee 9—Highways, of which C. I. Hartsell, division engineer, Chesapeake & Ohio Railway, Saginaw, Mich., is chairman. If Mr. Hartsell and members of his committee will come to the platform, we will get started with our program.

As the committee comes to the platform, I would like to tell you that the privilege of the floor is extended to all members of the Association and to all our guests. We invite your comments and criticism of reports in the limited amount of time which has been provided each committee for discussion. For your convenience in this regard, microphones with removable heads have been provided in each main aisle, and someone manning each microphone will be glad to bring it to you at your place on the floor, to the extent that this is possible.

I now present Mr. Hartsell, chairman of Committee 9.

CHAIRMAN C. I. HARTSELL: Mr. President, members of the AREA and guests:

The report of Committee 9—Highways, will be found in Bulletin 546, pages 245 to 258, incl. Since the Bulletin was issued our collaboration with the Signal Section, AAR and the Grade Crossing Protection Unit of Train Operation, Control and Signals Committee of the Operations and Maintenance Department of the Association of American Railroads has developed desirable changes in Subcommittee 8's report, which will be called to your attention when the subcommittee chairman presents his report. Committee 9 will report on four of its five assignments. We solicit any comments, suggestions, or criticisms on the committee report that you may care to offer. Each subcommittee chairman will give you an opportunity to express yourselves at the conclusion of his report.

Assignment 1—Revision of Manual.

CHAIRMAN HARTSELL: Subcommittee Chairman J. M. Trissal, vice president and chief engineer, Illinois Central Railroad, will present the report on Assignment 1.

J. M. TRISSAL: Mr. President, Mr. Chairman, members and guests:

In order to properly describe the reflecting medium intended for use on reflector type highway—railway grade crossing signs and to conform with other Manual descriptions, your committee recommends that the last sentence of paragraphs 2, 4, 5, and 6, column 2, page 9–2–1 of the Manual be revised to read as follows: "Reflective medium may be reflector buttons or reflex-reflecting material."

I move that the recommendation be adopted.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 2—Merits and Economics of Prefabricated Types of Highway–Railway Grade Crossings.

CHAIRMAN HARTSELL: R. E. Nottingham, division engineer of the Louisville & Nashville Railroad will present the report on Assignment 2. Mr. Nottingham.

R. E. NOTTINGHAM: Your committee submits a report of progress in determining the service life and initial cost for the various types of prefabricated materials now being used as crossing material.

The manufactured, treated-timber-panel type may be expected to last from 10 to 15 years and costs on the average about $25 per foot of track.

One metal-grating type installation which has been kept from being clogged up by road dirt, has required one-third less surfacing of the roadbed under the crossing compared with an adjacent shop-made timber panel crossing. In about 12 years the decreased maintenance will wipe out the increased initial cost of the metal-type material.

This metal crossing is expected to last 20 years. It initially costs $52 per foot of track. Other lighter-constructed metal-grating-type crossings, when allowed to become clogged up with dirt, failed within 8 years.

The 19 rubber-slab type crossings are giving good service with practically no main-

tenance so far. The initial cost is reported to be from $70 to $86 per foot of track. Since they are less than five years old, we can only report that it appears they will give a satisfactory long life under extremely heavy highway traffic conditions that caused other types to fail within a few years.

Concrete-slab-type crossings appear to be unsuited to present-day highway traffic.

All costs mentioned above were at the time of installation, within the last five-year period. The installation costs were after the track had been made ready.

We offer the report as information. Your committee desires to continue this assignment for further study and recommends this subject be continued.

Is there any discussion?

PRESIDENT MEYERS: Thank you, Mr. Nottingham. Your report will be so received.

Assignment 4—Recommended Device to Guard Highway–Railway Crossing Signs and Signals from Damage by Vehicular Traffic, Collaborating with Signal Section, AAR.

CHAIRMAN HARTSELL: F. C. Cunningham, division engineer, Chesapeake & Ohio Railway, will present the report on Assignment 4.

F. C. CUNNINGHAM: Mr. President, members and guests:

Your committee presents as information a drawing illustrating several types of barriers now being used to protect highway–railway crossing signals from damage by vehicles.

Investigation of this subject disclosed that at least one state requires use of a particular design of barrier; and this, together with the wide variance in local conditions over the country, indicates the undesirability of recommending some particular type of barrier for general use.

The committee recommends that the subject be discontinued.

Is there any discussion?

PRESIDENT MEYERS: If there is no discussion, we thank you, Mr. Cunningham, and your assignment will be discontinued.

I think this is a pertinent subject because I know on our road we have plenty of crossing signals that are knocked down, and usually you can never find out who did it.

Assignment 8—Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway, Collaborating with Signal Section, AAR.

CHAIRMAN HARTSELL: Due to circumstances beyond his control, Subcommittee Chairman D. W. Hughes could not be present. Also, because of the circumstances I told you about earlier, we have necessarily revised the report on Assignment 8 that Mr. Hughes was going to give. G. B. Blatt, chief signal, electrical and communications engineer, Reading Company, will now present the revised report.

G. B. BLATT: Mr. President, Mr. Chairman, members and guests:

The final report of Subcommittee 8 of Committee 9 on "Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway," Collaborating with Signal Section, AAR, will not be made at this meeting because additional time is required to study certain information recently presented to Committee 9.

The subject will, therefore, be continued and a report made at a later date.

Is there any discussion?

PRESIDENT MEYERS: Thank you, Mr. Blatt. I might say that the items that Mr. Blatt refers to are not the fault of the committee, but they did come into light recently, and it seemed advisable to study this information to make sure that what we put in the Manual will be the right thing.

CHAIRMAN HARTSELL: Mr. President, this concludes our formal committee report to the convention. However, we have a speaker we would like to present to you.

We are all acutely aware of the effect of trucks on railway traffic. Likewise, as individuals and engineers we are aware of the effect of trucks on highways. Some of us have heard of the road test of loaded vehicles in the eastern part of the United States. The results of that test were such that a special test is presently being conducted at Ottawa, Ill., by interested parties to determine just what effect truck traffic has on various types of highways. The project is under the administration of the Highway Research Board of the National Academy of Sciences—National Research Council. The chief engineer for the project is Mr. William N. Carey, Jr.

You may wish to know Mr. Carey's background. He is a native of Minnesota and a civil engineer graduate of the University of Minnesota in 1937. He has worked with contracting firms in Minnesota and Michigan, has been associated with the U. S. Engineers central laboratory to supervise the design and field control of construction of pavements on approximately 100 military airfields, and has set up soils laboratories and supervised the design of an earth-and-cement dam for the San Juan, Puerto Rico, water system, ending his army service as a lieutenant colonel.

Mr. Carey has authored many technical papers and reports on highway research and the three test road projects.

He is a member of the American Society of Civil Engineers, serving as the secretary to its executive committee. He is a member of the national honorary fraternity, Sigma Xi, and is a registered professional engineer.

He has many hobbies, including amateur radio.

His experience on road tests includes the Maryland, Idaho, and now the Illinois project.

We are indeed honored to have Mr. Carey as Committee 9's speaker. He will discuss the purpose and layout of the Illinois road test. Mr. Carey.

The AASHO Road Research Project

By W. B. McKendrick, Jr.
Project Director
and W. N. Carey, Jr.
Chief Engineer for Research

The AASHO road research project is a $22 million experiment aimed primarily at determining significant relationships between performance and traffic for highway pavements of known designs under controlled truck traffic with known loadings.

The project is sponsored by the American Association of State Highway Officials, and is being administered by the Highway Research Board of the National Academy of Sciences—National Research Council.

The cost is being borne by the states, District of Columbia, Hawaii, Puerto Rico, the Bureau of Public Roads, the Automobile Manufacturers Association, and the American Petroleum Institute, with cooperation and assistance from the Department of Defense.

The test is being conducted on six carefully constructed loops of pavement at Ottawa,

Ill., about 80 miles southwest of Chicago, in an area where climate and soils are typical of wide areas of the nation.

Nearly seven years of planning and preparation preceded the beginning of the research phase of the AASHO Road Test in October, 1958; and the project represents the cooperative effort of many persons from various phases of highway engineering, research and science.

Basic planning for the project was under a working committee of the AASHO Committee on Highway Transport. When this committee had completed its task, the Highway Research Board was requested to undertake the project, and over-all guidance was placed in the hands of a National Advisory Committee composed of representatives of several state highway departments, the Bureau of Public Roads, the Department of the Army, universities, related industry organizations, and highway user groups.

In addition, there are advisory panels which function in specific fields, such as statistics, soils, instrumentation, public information, materials and construction, maintenance, vehicles, bridges, performance rating, and economic data.

The Highway Research Board established a field office at the project site in 1955, and now has a staff of about 140 persons employed there. Research operations are organized under three principal branches—rigid pavements, flexible pavements, and bridges. These branches are supported by staff-level service branches in the fields of data analysis, vehicle operations, pavement maintenance, instrumentation, materials, and special assignments. The heads of these branches along with the project director, chief engineer for research, business administrator, and chief of public information comprise the project staff.

To provide personnel for operating the test vehicles, the United States Army Transportation Corps Road Test Support Activity was established by the Department of Defense. This is a special unit of about 300 officers and enlisted men who will be stationed at the project throughout the research phase of the test.

The AASHO Road Test is not only larger and more comprehensive than any previous large-scale highway research project, but is the first to be designed in accordance with modern scientific principles of experiment design.

Seven independent variables were selected for control at more than one level. The final selection was made after careful consideration from perhaps hundreds of possibilities by members of the National Advisory Committee. It was early agreed that orthogonal experiment designs would be used throughout. This decision meant in effect that every variable added practically doubled the size of the project. Thus, it was necessary to restrict severely the number of variables that will be studied. Those selected were considered by the committee to be the most important for consideration in a test of this type. They are:

1. Pavement surfacing type. Half of the test pavements are surfaced with portland cement concrete and half with bituminous concrete.

2. Surfacing reinforcement. Half of the concrete pavements are reinforced and half are plain.

3. Surfacing thickness. The asphalt concrete surfacing thickness varies in 1-in increments from 1 to 6 in. Sections with surface treatment are also included.

Concrete slab thicknesses vary across the job in 1½-in increments from 3½ to 12½ in. Certain sections 2½ in thick are included.

4. Base thickness. Under the flexible pavements crushed stone base varying in 3-in increments from 0 to 9 in thick are included.

5. Subbase thickness. Under the concrete slabs, sand-gravel subbase with thicknesses from 0 to 9 in. in 3-in increments are included.

Under the flexible pavements subbases in 4-in increments range from 0 to 16 in thick.

6. Axle spacing. On the main test loops half of the vehicles are single-axle tractor semi-trailers, the other half are tandem-axle tractor semi-trailers.

7. Axle load. Single axle loads on the project range from 2,000 to 30,000 lb. Tandem axle loads from 24,000 to 48,000 lb.

Special side studies permit consideration of base-type (crushed stone, crushed gravel, bituminous treated sand-gravel, and cement treated sand-gravel) and the effect of paved shoulders. There are also included 16 test bridges designed to permit study of behavior of structures under high stresses.

Controlled traffic with known axle loads and axle spacing is being operated at a rate of about 50 vehicle trips per hour for 18 hr a day, 6 days a week. This traffic density is heavier than that found on most highways of the nation but lighter than that on some heavily traveled truck routes. Any given pavement section will be subjected only to loads of a given magnitude in order that the effect of load may be clearly demonstrated. A constant speed of 30 mph for the test traffic was chosen since strains and deflections in pavements do not increase appreciably at higher speeds and since the cost of right-of-way and construction for the turnarounds designed for higher speeds would have been prohibitive.

Construction of the test facility, which extends along an 8-mile right-of-way, began in the late summer of 1956 and was completed in the fall of 1958. It was accomplished under controls more strict than any ever attempted in large-scale highway construction. These controls were directed at producing an embankment and pavements which were uniform in quality throughout the entire job, so as not to introduce additional variables.

Construction of the earth embankments began in late August of 1956. By mid-November, when operations were suspended for the winter, more than a million and a quarter cubic yards of earth had been moved and the embankments were about 95 percent completed.

The upper 3 ft of the embankment material—about half of the total cubic yardage—was placed under rigidly controlled conditions. The material, a fine-grained clay, was hauled from three borrow pits adjacent to the right-of-way, and placed in 6-in loose lifts.

Each lift was processed with rotary tillers which thoroughly mixed the soil and added the proper amount of water.

The loose soil was then compacted to 4 in by pneumatic-tired rollers loaded to 15 tons.

Specifications for the embankment called for holding density between 95 and 100 percent of standard AASHO maximum, and moisture content between $\pm$ 2 percent of optimum.

In order to preserve this carefully controlled compaction, all of the equipment working on the embankments was required to operate in controlled patterns, and no equipment was allowed to turn around or cross over the embankments except in designated transition areas which are not a part of the test sections.

During the earthmoving phase of the job, the contractors—S. J. Groves and Sons Company and Arcole Midwest Corporation—assembled a large concentration of heavy equipment in order to operate simultaneously in the four main test loops. At one period,

it was estimated that some 225 pieces of equipment valued in excess of $5 million were on the job.

The embankments were completed and subgrading began in the 1957 construction season. Mechanical subgraders, riding on forms, brought the embankment to exact grade. The specifications permitted a tolerance of ± 1/8 in. This same operation was also carried out on succeeding layers of base and/or subbase, making it necessary to set forms twice on the rigid pavement tangents and three times on the flexible pavement tangents.

Another interesting feature of the specifications was the banning of all heavy hauling equipment from the center 27 ft of the embankments. This meant that the subbase and base material was placed with equipment operating from the shoulder area of the roadway.

The subbase material is a sand-gravel mixture procured from a pit near the job site. The pit-run material was washed, screened and run through a batching plant in order to closely control the gradation. This material was placed on the subgrade by a conveyor belt system and a spreader pushed by a tractor.

The base material—a crushed limestone—was produced to specifications by a quarry near Romeoville, Ill., and brought to a point near the job site by rail. This material was placed by running it through a modified paver which added water and employed a conveyor belt on its boom to carry the material to a self-propelled spreader.

The contract for paving the test loops was awarded in late August 1957 to the S. J. Groves and Sons Company, which subcontracted the asphaltic concrete paving to Rock Road Construction Company

The remainder of that construction season was utilized to bring in equipment, set up plants, and construct pilot test sections. The pilot test sections, built between the main loops, allowed the engineers and contractors to experiment with various methods and equipment in placing paving to meet the specifications. For example, the rigid pavement pilot test section included placing of 2½-in and 3½-in reinforced concrete slabs. These thin sections do not represent normal practice, and special techniques were required.

Some portland cement concrete pavement was placed on the loop turnarounds before operations were suspended for the winter.

At the beginning of the 1958 construction season, it was apparent that an all-out effort was needed if the target date for completion of construction was to be met. Some appreciation of the magnitude of this effort can be gained from the fact that the combined forces of the contractors and the project totalled nearly 700 persons at the height of operations.

Placing the portland cement concrete paving was begun on the test tangents on May 19. Two identical paving outfits were placed in operation, and the work proceeded rapidly. The final section of rigid pavement was placed on July 10.

On the flexible pavement tangents, it was, of course, necessary to place an additional layer of material—the crushed-stone base. Considerable preliminary work also was required on a pilot test section where various mix designs were tried, as well as various roller types, weights and rolling patterns for the different thicknesses of asphaltic concrete surfacing.

The first asphaltic concrete was placed on the test tangents on July 9, and the final piece of surface course was placed on September 24. Here, again, was an example of an unusual operation.Trucks carrying the asphaltic concrete from the plants were not allowed

to operate on the center portion of the grade where they could dump directly into the paver. Instead, the trucks remained on the shoulder area, and the asphaltic concrete mix was transferred to the paver by a pneumatically operated shovel.

The final construction work consisted of bringing shoulders up to grade, joint sealing, seeding, and surface treatment of frontage roads. This work was complete when test traffic was officially inaugurated on October 15.

Obviously, large-scale highway construction, carried out under rigid specifications, required a huge program of sampling, testing and inspection. Qualified engineers supervised a corps of technicians in this phase of the job. Many thousands of samples were taken, both at the source of the materials and on the job. During some phases of the work, production line methods were needed to handle the continuous flow of samples.

One piece of equipment that was highly important in the materials testing program was a continuous drying oven, designed by staff members and built locally. This oven required only 23 min to dry a sample of material as opposed to the several hours required in a conventional oven.

Another interesting piece of test equipment was a device which employs nuclear energy to determine the density of materials. The operation of this equipment is based on the fact that the attenuation of gamma radiation increases with increase in density. Experimentation with this equipment has been under way at the project for about two years, and the device was used to determine in-place density of the base course material.

During the final construction season of the spring and summer of 1958, the project purchased and made ready the fleet of 70 vehicles which are now being operated over the test pavements. The vehicles were purchased on a competitive bid basis, so arranged that no one manufacturer could monopolize the test vehicle fleet.

As a result there are 10 different makes of trucks and tractors and 7 different makes of semi-trailers being used on the job. These include Ford, Chevrolet, GMC, Dodge, International Harvester, Reo, White, Mack, Diamond T, and Autocar trucks and tractors; and Andrews, Kingham, Lufkin, Highway, Hobbs, Dorsey, and Alabama semi-trailers.

The vehicles were loaded with concrete blocks tied down with steel bands. The first attempts at loading employed hollow-core building blocks in order to hold down the over-all density of the loads and make them somewhat comparable to average on-the-highway loads. It was discovered, however, that these loads resulted in a center of gravity too high for safe operation on the 200-ft radius turnarounds on the main loops. As a result, many of the building blocks have been replaced with solid concrete blocks.

The vehicles are being operated in 10 traffic lanes in 5 of the 6 test loops. The smallest loop, with 2000-ft tangents, is being used to provide information on the behavior of the pavements with no traffic whatsoever, and for special tests under static loading. Another small loop, with 4400-ft tangents, is subjected to the lightest axle loads—2000 single on one lane and 6000 single on the other lane.

The other four loops, generally called the "main" test loops, have 6800-ft tangents. The axle loads in these loops are 12,000 single and 24,000 tandem, 18,000 single and 32,000 tandem, 22,400 single and 40,000 tandem, and 30,000 single and 48,000 tandem. The latter two loads are heavier than any allowed on the highways today.

The tangents of the test loops are subdivided into structural sections 24 ft wide and made up of various thicknesses of surface, base and subbase. Fexible pavement sections are 100 ft long; reinforced concrete sections are 240 ft; and plain concrete sections are 120 ft. All sections are separated by short transition areas.

Within any given tangent the experiment design calls for a complete factorial in which all levels of each selected variable appear in combination with all levels of every

other variable. For example, in the flexible tangents of one test loop, there are three thicknesses of asphaltic concrete (3, 4 and 5 in), three thicknesses of crushed stone base (0, 3 and 6 in), and three thicknesses of sand-gravel subbase (0, 4 and 8 in). All possible combinations of these thicknesses are included to make a 3x3x3 factorial with a total of 27 different structural sections. Some of these sections are replicated, or repeated, in the tangent; and some special study sections are included to make a total of 42 structural sections. Since traffic on the inner lane carries one axle load, and traffic on the outer lane carries another axle load, each 12-ft lane is considered to be a separate test section. Thus, there are 84 test sections in this tangent. On the entire project, the number of test sections is 836, and all are located at random within their respective tangents.

The Army personnel operating the test vehicles are quartered in a $450,000 housing-administration area provided by the project. Drivers work in two shifts per day on a schedule which is shifted every two weeks so that traffic coverage during day and night hours is about equal. Operations are halted on Sundays, and each driver is also off duty one other day per week. On a normal shift, a driver is on duty about 10 hr. However, a 10-min break each hour, and half-hour meal periods, make actual driving time about 7½ hr per shift. It has, of course, been realized that the drivers provide an excellent opportunity for studies of fatigue and the effects of monotonous driving conditions. Plans for such studies are being made by the appropriate agencies.

The effects of the controlled test traffic on the pavements are being measured and recorded by means of a complex system of electronic and mechanical instruments and data handling equipment. Many of the instruments are entirely new, developed specifically for this project, and represent in themselves an important step forward in highway research. The majority of the devices are electrical in nature and, therefore, are highly sensitive, and can be placed in otherwise inaccessible spots, can detect phenomena which take place too fast for visual observation, and can be used with automatic recording equipment.

Electric transducers installed on or in the pavements include strain gages, thermocouples, frost depth indicators, curvature strips, and conventional linear differential transformers to measure deflection.

Measurements from these transducers are recorded on electronic equipment installed in movable vans which can plug into terminal boxes along the roadway and record transient behavior of the pavement as the test traffic is running.

This recording equipment is designed to digitize the output of the electrical transducers and to punch the data into paper tape.

The tape is then brought into the project's data processing center where the data are transferred to punched cards. A fairly complete IBM set-up is installed at the project for handling the data.

Analysis of the data will be done to a great extent on a Bendix G15–D digital computer which is also installed at the project. However, some of the more cumbersome and time-consuming analyses will be done on larger computers at nearby universities.

Perhaps the most interesting of the instruments in use on the project are those deisgned to measure surface deformation.

These include an automatic model of the "Benkelman Beam," an instrument designed to measure and record surface deflections in flexible pavement near the rear wheels of a loaded trailer. This device operates automatically at regular intervals as the vehicle moves along the roadway at about 3 mph. Its 7 probe arms measure 11 deflections, and the data are automatically recorded on equipment carried on the trailer.

There is also a transverse profilometer, consisting of a truss supporting nine pneumatically operated probes. This device is carried along the roadway by a van and placed down at any desired spot. It can be used to provide a nine-point profile; or by employing the probes in groups of three, to read directly the rut depth in flexible pavements. The recording equipment installed in the van can be used to automatically average the readings from the two outer probes and subtract this average from the reading of the center probe, thus giving a direct depth-of-rut result.

Perhaps the most difficult of the instrumentation problems was the development of a longitudinal profilometer. This device measures and records, on oscillograph tape, the slope of the pavements in the wheel paths of the test vehicles. It operates as the trailer is towed along the roadway at about 7 or 8 mph. Development of this instrument included, among other things, a unique horizontal reference system.

The longitudinal profilometer is one of the most important devices on the project, and will be used frequently. It is estimated that during the two-year test period, it will produce an actual 42 miles of oscillograph tape. Turning this analog record into digital form entails reading the tape at intervals of about seven per inch. Therefore, an automatic chart reader is used for this task. The digitized information is punched into paper tape which can be run directly into the computer for analysis.

It is obvious that with equipment such as has just been described that a large amount of data will be generated. It has been estimated that the test will produce some hundreds of millions of pieces of data. If it were not for automatic recording equipment and electronic computers, it would be impossible to conduct an experiment of this magnitude.

It is difficult to say at this point in the research just what form the final findings will take or exactly how they will be used by highway administrators and engineers. However, some idea of the nature of what is being sought can be gained from the official objectives of the test. These objectives have determined much of what has and what will be done at the test site. They are:

1. To determine the significant relationships between the number of repetitions of specified axle loads of different magnitude and arrangement and the performance of different thicknesses of uniformly designed and constructed alphaltic concrete, plain portland cement concrete, and reinforced portland cement concrete surfaces on different thicknesses of bases and subbases when on a basement soil of known characteristics.

2. To determine the significant effects of specified vehicle axle loads and gross vehicle loads when applied at known frequency on bridges of known design and characteristics. The bridges will include steel I-beam design, conventional reinforced concrete design, and prestressed concrete design.

3. To make special studies dealing with such subjects as paved shoulders, base types, pavement fatigue, tire size and pressures, and heavy military vehicles, and to correlate the findings of these special studies with the results of the basic research.

4. To provide a record of the type and extent of effort and materials required to keep each of the test sections or portions thereof in a satisfactory condition until discontinued for test purposes.

5. To develop instrumentation, test procedures, data, charts, graphs, and formulas, which will reflect the capabilities of the various test sections; and which will be helpful in future highway design, in the evaluation of the load-carrying capabilities of existing highways and in determining the most promising areas for further highway research.

The first objective, of course, embodies the basic purpose of the project. Stated simply, it asks for significant relationships between performance and traffic for pavements of certain designs under controlled truck traffic with certain loadings.

There are two key words in this objective: significant and performance. The word significant, in this case, does not relate to someone's judgment of what is and what is not meaningful. It is used here in its mathematical sense. That is, if a relationship is said to be significant, there is a stated probability that it is truly so within the environment of the experiment. A significant relationship may be defined as one in which the effects on one variable are known to be caused by the other variables with a specific degree of certainty.

In order to make statements about the significance of relationships, an experiment must be designed in accordance with certain principles of mathematical statistics. This has been done at the AASHO Road Test; and the test is—in terms of time, space and cost—probably the largest statistically designed experiment ever undertaken.

One very important feature of the design of the experiment is the use of the complete factorial in which each design factor level occurs in combination with all other design factor levels. Such a design makes it possible to estimate the effects of design factors and their interactions independently of one another. In other words, if two test sections of different thickness are subjected to the same traffic and one behaves better than the other, it will be possible to deduce whether the difference in behavior is attributable to the difference in thickness or not. In previous road tests no such deduction has been possible.

Two other important features in the design of the test facility were randomization in the layout of the experimental units, and replication, or repeating of experimental units, at least on a limited basis.

Randomization, in effect, "shakes loose" the effects of the design factors from the effects of error variables so that unbiased estimates are obtained for design factor effects. In simple terms, randomization is nothing more than what is accomplished by shuffling a deck of cards. Any card has an equal chance of being anywhere in the deck. At the road test, any test section had an equal chance of being anywhere on its respective loop tangent, and the loops themselves are located along the right-of-way in random order.

Replication, or providing more than one experimental unit with the same design factor levels, amounts to performing the same experiment twice. This provides the means for measuring experimental error so that the reliability of the results can be appraised. Thus, there are, in the test facility, a certain number of identical test sections being tested under identical axle loads.

The second key word of the first objective of the test is performance. The objective asks for significant relationships between the performance of pavements with different structural characteristics and the number of applications of a specific axle load.

Performance is necessarily a relative thing; and whether a pavement, or any other product, performs well or performs badly can never be anything except a matter of human judgment.

There is, however, a method of utilizing the collective judgment of a group of persons to validate indices derived from objective measurements. This method will be followed at the road test by using a performance rating panel composed of 13 men with backgrounds in highway engineering.

The process of deriving a "performance index" for any test section begins with the panel making individual "present serviceability" ratings of selected test sections. In evaluating a test section, the rater considers only the present ability of the section

of pavement to serve high-speed, high-volume mixed traffic such as might be found on an interstate highway. He may rate the pavement as "good" even though he strongly suspects it may fail in the near future.

The mean present serviceability rating of the panel is then used to validate an index made up of a weighted sum of terms involving measurable elements of pavement behavior such as roughness, cracking, faulting, etc. When an appropriate summation of these elements is obtained, the present serviceability rating of any test section can then be determined without an actual rating by the panel. There will be, however, periodic ratings by the panel to check the validity of the indices.

Once a number of present serviceability ratings are obtained, they can be plotted against number of load applications or against time. This plot will represent the performance of a test section. The panel is then called upon to make a performance rating after examining the plot of present serviceability against time. A performance index is then derived in the same manner as the present serviceability index.

Although many variables will be analyzed, the performance index is the main dependent variable in the test and will be plotted as ordinate against the independent variables in studies of the relationships called for by the first objective. Once this index is established, the analysis becomes a matter of determining appropriate mathematical models for relationships between the index and the controlled variables of the experiment. Analysis of the data with respect to these models will determine the extent to which the controlled factors affected the performance index.

There is one further step—the development of a future condition index which can be used to predict the condition of a highway at some future date if it is to be subjected to known loading and environment. Some of the elements in this index may be the same as those in the present serviceability index, but it will also probably include such measurements as strains and deflections. The index will, of course, be validated by comparing predicted conditions with actual conditions on the future date.

Bridge research at the AASHO Road Test is being carried out as 16 separate case studies on spans built at four locations in the two main traffic loops carrying the heaviest axle loads. Eight spans were constructed with steel I-beams, four with conventional reinforced concrete beams, and four with prestressed concrete beams. All are simple 50-ft spans with three beams and a reinforced concrete deck.

The bridge studies have two principal objectives: (1) To determine the behavior of short-span highway bridges under repeated applications of overstress; (2) To determine the dynamic effects of moving vehicles on short-span highway bridges.

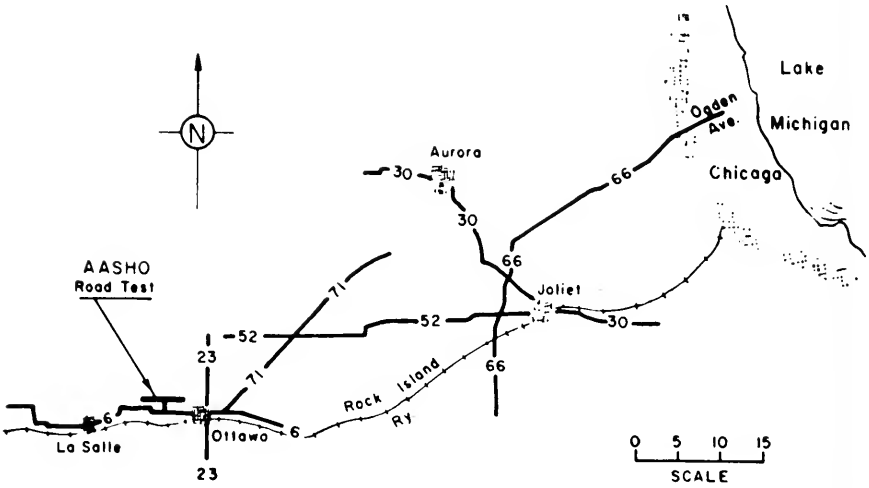
The 16 spans were all designed at higher-than-usual stress levels, with some of the steel beam bridges being designed at stress levels which approximate the yield point of the steel.

The design of the three types of bridges were based on different criteria each aimed at answers to problems peculiar to the type involved. Because of the differences in the design criteria, there is no basis for comparison between the steel, prestressed and reinforced concrete test structures.

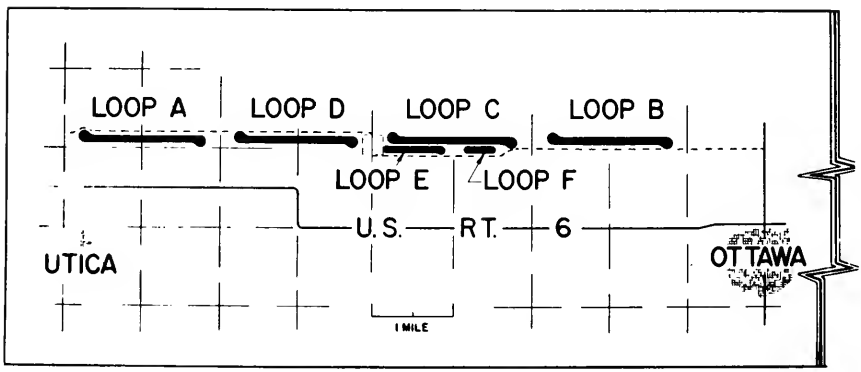
Four spans showed early distress and permanent distortion of such magnitudes as to cause their removal from the test. Nonetheless, considerable valuable data on their behavior were obtained.

The foregoing has been an attempt to present in brief what has been done at the AASHO Road Test and what it is hoped to learn from it. An earnest attempt is being

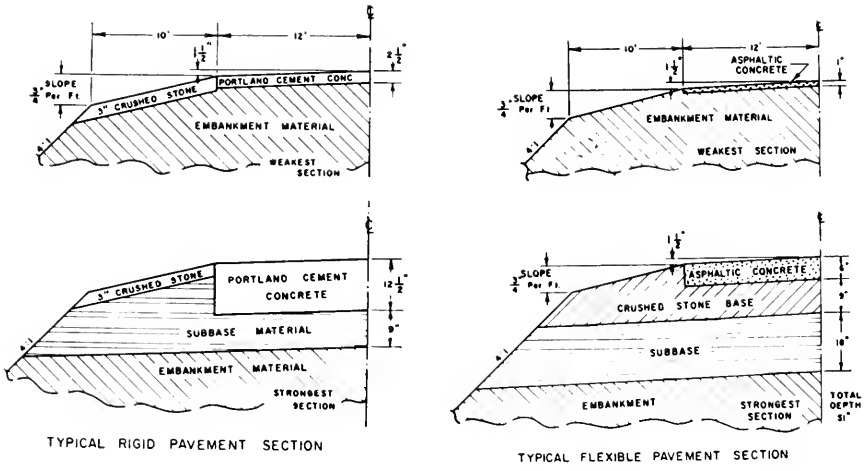
(Text continued on page 1035.)



Location map.



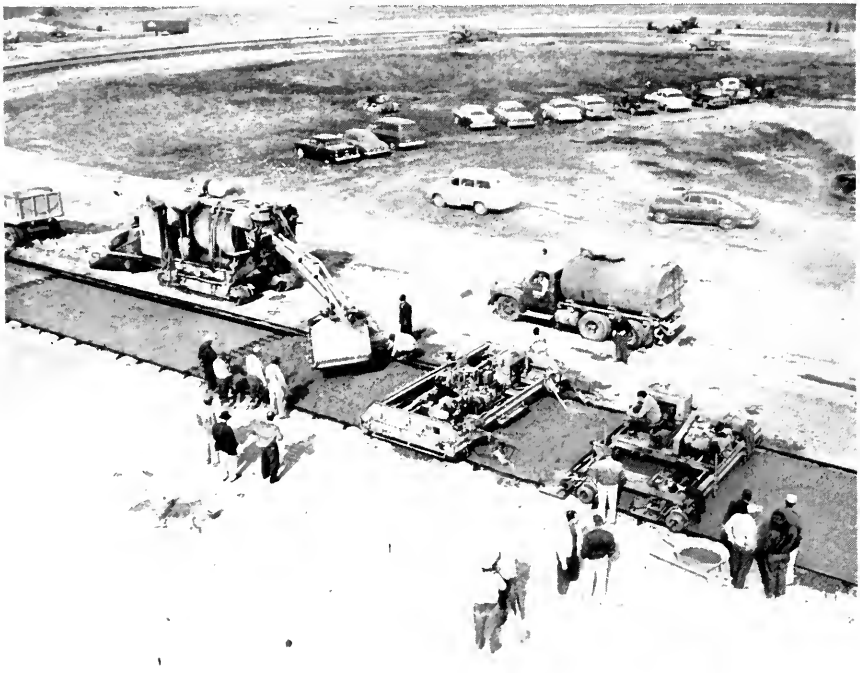
Layout of test loops.



TYPICAL RIGID PAVEMENT SECTION

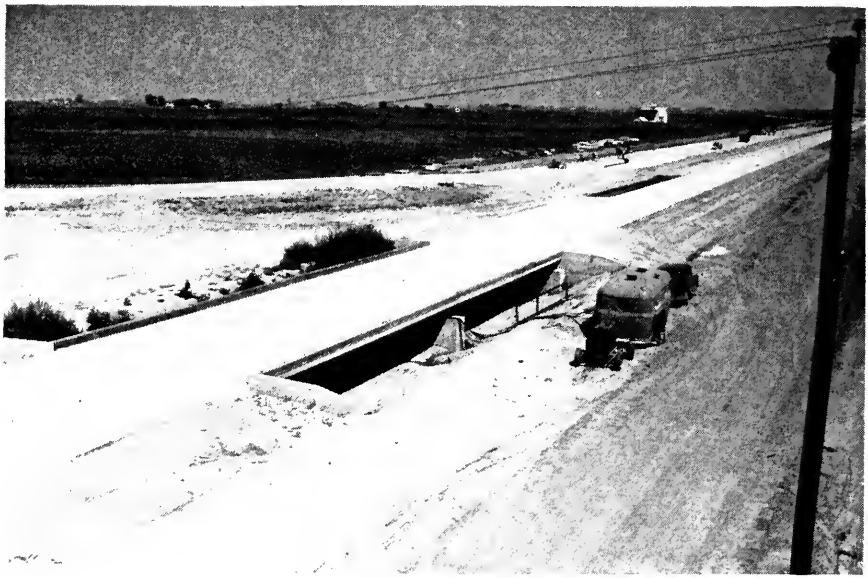
TYPICAL FLEXIBLE PAVEMENT SECTION

Typical cross sections of rigid and flexible test road construction.

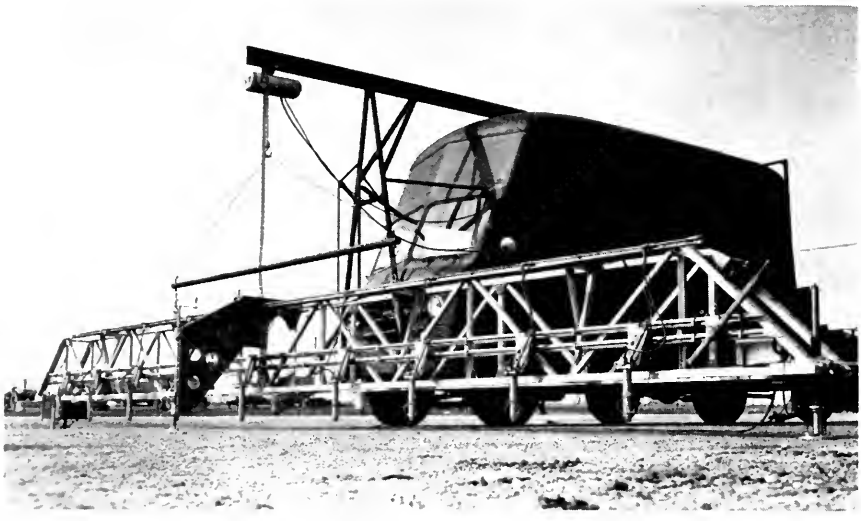


Concrete pavement operation.

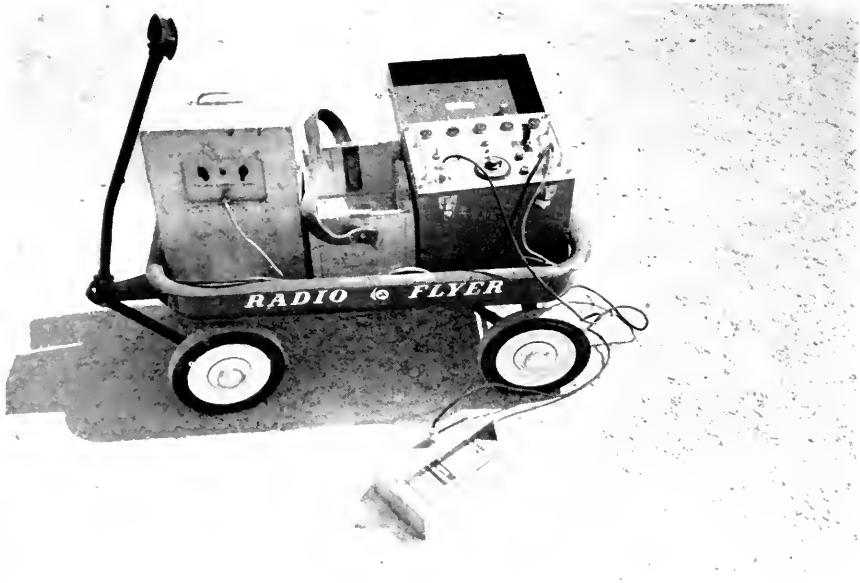
Flexible pavement operation.



Four of 16 test bridge slabs.



Transverse profilometer. This instrument measures depth of ruts in the traffic wheel path.



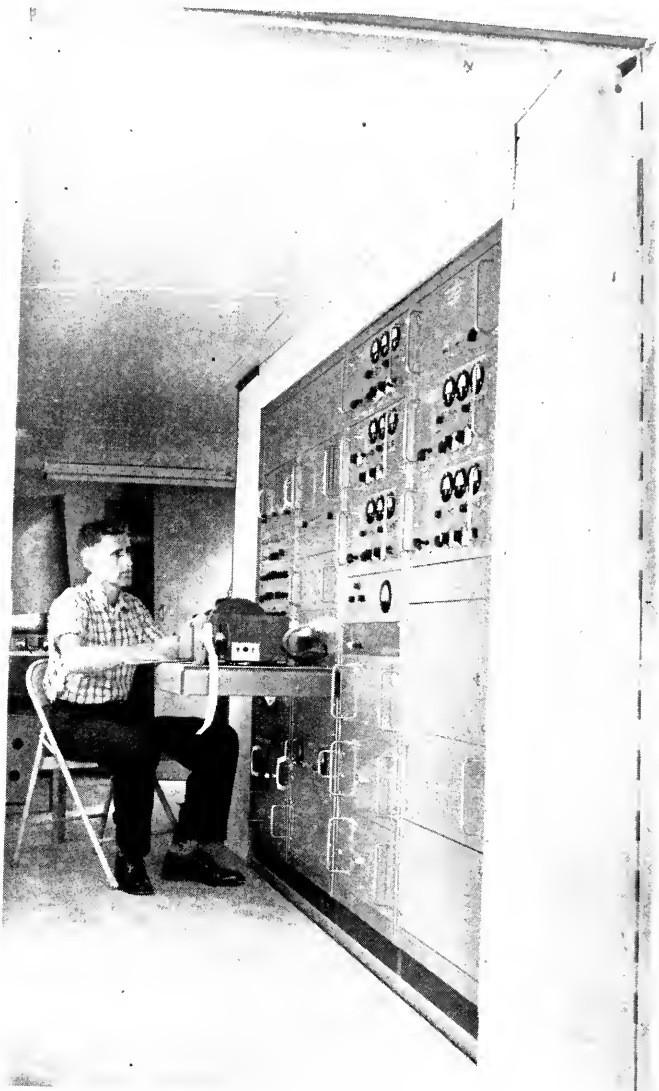
Field unit for nuclear measurements of construction densities.

Traffic in operation on one of the test loops after a snow storm.

Test truck on flexible pavement tangent.

Tape to card punch. Data are recorded on perforated paper tape in the field and transferred to punched cards in the processing center.

Test vehicle passing instrument van. Such vans contain instruments to measure deflections and strains under traffic.



Instrument van interior view.

Automatic Benkelman Beam measures deflection of pavement surface under load.

made to obtain information most needed by highway administrators and engineers. Of course, the findings will also be useful to many others. The Bureau of Public Roads, for example, intends to use data from the test in studies it is making of highway cost allocation, and on the maximum desirable dimensions and weights of vehicles to be operated on the federal aid highways, including the interstate system.

The test traffic is now under way, and the collection and analysis of the vast amount of data have begun. The policy at the present time is that all data from the research phase of the test will be restricted until completion of the testing program. It is hoped, however, that the use of modern data handling techniques and analysis by electronic computers will enable the research staff to keep analysis close behind the actual collection of data. In view of this, it should be possible to produce reports containing the over-all findings of the test some time in 1961.

In the meantime, preliminary reports will be published by the Highway Research Board. These reports will cover the basic concepts and planning for the project, the construction of the test facility, the plans for the collection and analysis of data, etc. They will provide the background necessary for a complete understanding of the project. [Applause]

CHAIRMAN HARTSELL: Thank you, Mr. Carey, for a most informative and interesting discussion. I believe we railway engineers now have a better understanding of the how, what, and whys of the road test.

It has been my pleasure to serve this committee and the AREA as vice chairman for three years and as chairman for the past three years. I wish to express my thanks to the Association for this privilege. To the members, members emeritus, associates and

guest members of the committee I wish to state that it was an honor and pleasure to serve you. Your willing assistance and cooperation were excellent and greatly appreciated by me.

May I now introduce the new vice chairman of the committee, R. W. Mauer, assistant engineer, Office of Chief Engineer, Atchison, Topeka & Santa Fe Railway, Chicago. [Applause]

Your incoming chairman of Committee 9—the able vice president and chief engineer, Illinois Central Railroad, Chicago, J. M. Trissal. [Applause]

Mr. President, this concludes Committee 9's report.

PRESIDENT MEYERS: Thank you, Mr. Hartsell, for your very interesting report, and I want to thank you, too, Mr. Carey. I can remember a number of years ago, going to Maryland where similar projects were under way but on a very small scale, and they did not have the electronic equipment available today. I hope sometime this summer to stop in at Ottawa and see the present road test. I am sure many others are interested, too.

Mr. Hartsell, it is with a sense of appreciation that we look back over the work of your committee for the past three years. We welcome as your successor, Mr. Trissal, and your new vice chairman, Mr. Mauer, knowing that these two able men will carry forward effectively the work which you have directed so capably during the past three years.

Your committee is now excused with the thanks of the Association.

Discussion on Contract Forms

[For report see pp. 301–314]

[President Meyers presiding.]

PRESIDENT MEYERS: To save time, will Committee 20 please come to the platform. The chairman of this committee is E. M. Hastings, Jr., wire crossing engineer system, Chesapeake & Ohio Railway.

Mr. Hastings, you may now proceed with your report.

CHAIRMAN E. M. HASTINGS, JR. Mr. President, members of the American Railway Engineering Association, and guests:

Your Committee on Contract Forms has five assignments. Three of them are a continuation from last year, two are new. Our reports appear in Bulletin 546, beginning on page 301.

Assignment 1—Revision of Manual.

CHAIRMAN HASTINGS: W. R. Swatosh, assistant superintendent of construction on the Erie Railroad is chairman of Subcommittee 1 and will present the report.

W. R. SWATOSH: Mr. President, members, and guests:

Your committee offers the following with respect to the Manual: Delete from the Manual the agreement found on pages 20–7–8 and 20–7–9, and replace it with the form entitled "Form of Agreement to Permit Subsurface Exploration on Railway Property," as published on pages 302 to 304 in Bulletin 546. The text of the revised form is similar to the existing one but includes under "Notes" an alternate Sec. 4. Indemnity, and 4a. Insurance, to cover the preparation of an agreement with an agent of a governmental body, a private party or a corporation, thus widening its application. It is pointed out that the basic form as prepared will only indemnify the legal liability of the Railway Company. The agreement when written to comply with the notes will indemnify the Railway Company's legal liability as well as its sole negligence and provides for

insuring the contractual liability assumed. Mr. President, I move that this new form be approved for publication in the Manual.

[The motion was duly seconded, was put to a vote, and carried.]

MR. SWATOSH: That finishes the report of my subcommittee, sir.

PRESIDENT MEYERS: Thank you, Mr. Swatosh.

CHAIRMAN HASTINGS: Thank you, Mr. Swatosh. I would like to mention that Mr. Swatosh is stepping down from the chairmanship of Subcommittee 1 at the close of this convention. I want to express the appropriation of the Association, Committee 20, and myself for his years of valuable service in this important position.

Assignment 2—Form of Lease Covering the Use of Railway Tracks for Storage of Tank Cars Containing Liquefied Petroleum Gases, Anhydrous Ammonia, and other Flammable or Dangerous Materials, Collaborating with Fire Protection and Insurance Section, AAR.

CHAIRMAN HASTINGS: Our next report is on Assignment 2. W. D. Kirkpatrick, assistant to chief engineer of the Missouri Pacific is chairman of the subcommittee and will present the report.

W. D. KIRKPATRICK: Mr. President, members of the Association and guests:

Assignment 2 was given to our committee by special action of the Board Committee on Outline of Work at the urgent request of R. G. May, vice president, operations and maintenance department, AAR, in June of last year. We have prepared a tentative form of agreement, which appears in the Bulletin, as a guide for those of you who may need one. We would appreciate receiving, in writing, your criticisms and suggestions, as we want to present this subject as Manual material next year.

PRESIDENT MEYERS: Thank you, Mr. Kirkpatrick.

CHAIRMAN HASTINGS: Thank you, Mr. Kirkpatrick, for the excellent job you have done on this subject in such a short time.

Assignment 3—Form of Lease Covering Right to Strip Mine on Railway Miscellaneous Physical Property.

CHAIRMAN HASTINGS: Our next report is on Assignment 3. D. F. Lyons, assistant engineer, Chicago, South Shore & South Bend Railroad, is chairman of this subcommittee and will present the report.

D. F. LYONS: Mr. President, members of the Association and guests:

We have been studying this subject this year and hope to have a tentative form of agreement to submit to you next year.

CHAIRMAN HASTINGS: Thank you, Mr. Lyons.

Assignment 4—Form of Agreement Covering Parallel Occupancy of Railway Right-of-Way Property by Electric Power Lines, Collaborating with Electrical Section, AAR.

CHAIRMAN HASTINGS: We unfortunately lost, by accidental death, "Kenny" Begemann, the chairman of this subcommittee. He was a hard working committee member and, needless to say, we miss him.

I would like to thank Frank Youngwerth and C. O. Ellis as collaborators from the AAR for their able assistance in the preparation of this agreement. Mention of the collaboration was inadvertently left out of the Bulletin.

Last year we presented as information a tentative form of agreement on this assignment and asked for your criticism. This year we are presenting, for publication in the Manual, the agreement presented in the Proceedings, Vol. 59, 1958, pages 435 to 439.

Mr. President, I move that the Association accept this agreement as Manual material and that it be published at the end of Part 3, Electrical Agreements, Chapter 20.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 6—Form of Agreement for Construction and Maintenance of Highway–Railway Grade Separation Structures for Public Roads.

CHAIRMAN HASTINGS: Our next report is on Assignment 6. J. L. Perrier, division engineer, Chicago & North Western Railway, is chairman of this subcommittee and will present the report.

J. L. PERRIER: While there is a good deal of verbiage necessary to cover the details of procedures in an agreement of this type, the principal features have to do with apportionment of expense and liability. Before the first skeleton drafts were prepared your committee studied the statutory requirements of various states with respect to these two items. It was obvious from the beginning that no single form could be drafted that could serve as a standard in all states under present laws, rules, or customs. However, we feel that the form as presented will serve as a guide in the preparation of such agreements. We also hope that it will be of some help to those organizations which are striving for standardization and unification of statues pertaining to grade separation projects.

Your subcommittee presents as information a draft of form of agreement, which is published on page 308 of the Bulletin. We invite your comments, criticisms and suggestions.

PRESIDENT MEYERS: Thank you, Mr. Perrier. It will be so received.

CHAIRMAN HASTINGS: Thank you, Mr. Perrier. This is a most important subject, and I hope the members of the Association will give you some valuable comments. You have done an excellent job on this assignment.

I would like to acknowledge the valuable assistance and the contributions to our committee work of J. V. McHugh, C. D. Dawson and F. A. Plesser, representatives of the Fire Protection and Insurance Section of the AAR.

In conclusion, I would like to thank Neal Howard and his staff, my subcommittee chairmen, and all the members of Committee 20 for their assistance in the preparation and presentation of this year's work of this committee. No chairman could ask for finer cooperation than I have received.

Mr. President, this concludes the report of Committee 20.

PRESIDENT MEYERS: Thank you, Mr. Hastings, and members of your committee, for the continued valuable work you do in behalf of our Association. I am sure we all appreciate the value of properly prepared contracts from the standpoint of the railroads.

Your committee is to be particularly commended for the prompt action on its part in coming up with one year with a tentative draft of a form of lease covering the use of railway tracks for the storage of tank cars containing liquefield petroleum gases. A recommended standard form of lease of this type is very much needed.

Your committee is now excused with the thanks of the Association.

[Vice President F. R. Woolford assumed the chair.]

Discussion on Engineering and Valuation Records

[For report see pp. 565–594]

[Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: According to our program, the next committee to make report is our Committee 11—Engineering and Valuation Records, of which Morton Friedman, chief valuation engineer, New York Central System, New York, is chairman. Will Mr. Friedman and members of his committee come to the platform and present their report at this time.

May I ask that the chairman, vice chairman, and secretary of the committee, and all reporting subcommittee chairmen take seats as near the podium as possible. Mr. Friedman, you may proceed with the presentation of your report.

CHAIRMAN MORTON FRIEDMAN: Thank you, Mr. Woolford.

Mr. President, members of the Association and guests:

The complete report of Committee 11 is published in Bulletin 548, January 1959, on pages 565 to 594, incl. During the past year the committee held three meetings at which its assignments were reviewed and discussed. This year we are reporting on eight of the ten assignments, one being a final report.

We regret to report the death of A. T. Powell on January 26, 1959. Mr. Powell retired as assistant chief engineer of the Grand Trunk Western Railroad on August 31, 1958. He was a member of long standing in the Association and of Committee 11, and will be remembered as an active worker and a good friend. A memoir to him will be prepared and published in a subsequent Bulletin.

Assignment 1—Revision of Manual.

CHAIRMAN FRIEDMAN: W. A. Krauska, draftsman, Missouri Pacific Railroad, will now present the report on Assignment 1. At the conclusion of each report you are invited to discuss and comment on the report and to ask questions of the speaker.

W. A. KRAUSKA: For the report on Assignment 1—Revision of Manual, we refer you to pages 566, 567, and 568 of Bulletin 548.

[Mr. Krauska then read the report on Assignment 1 as printed on the aforementioned pages, moving that the recommendations set forth be adopted and published in the Manual.]

[The motion was duly seconded, was put to a vote, and carried.]

CHAIRMAN FRIEDMAN: Thank you, Mr. Krauska.

Assignment 2—Bibliography on Subjects Pertaining to Engineering and Valuation Records.

CHAIRMAN FRIEDMAN: J. Bert Byars, assistant to chief engineer, Denver & Rio Grande Western Railroad, will now present the report on Assignment 2.

J. BERT BYARS: The report of Subcommittee 2 as printed in the Bulletin lists publications containing articles pertaining to valuation and accounting published during 1958.

These articles are concerned with depreciation accounting and valuation and their importance to the railroads in rate making; also the problems which railroad companies face in seeking to control losses from unprofitable operations through discontinuance.

Are there any questions or discussion concerning this report?

E. P. HACKERT [Denver & Rio Grande Western]: Mr. Byars, in order to help young engineers, is there any place where literature can be obtained concerning ICC accounting?

MR. BYARS: There is a publication by B. H. Moore available entitled "Working on the Tracks," which is distributed through the Association of American Railroads. It has pictures and illustrations showing the actual materials as you see them in the track and also the correct ICC accounts for charging out these materials. He also has a book out called "Working in the Shop."

Are there any other questions?

VICE PRESIDENT WOOLFORD: Thank you, Mr. Byars.

Assignment 3—Office and Drafting Practices.

CHAIRMAN FRIEDMAN: W. M. Ludolph, retired assistant engineer of the Milwaukee Road, will now present the report on Assignment 3.

W. M. LUDOLPH: Mr. Chairman, members and guests:

Your committee presents this report as information. On account of the great differences in record materials that have been used from time to time, as well as the variations that have been experienced in regard to their life, it is not possible with our present knowledge to predict the life of any record even if the conditions under which it is to be kept are known.

This report should, therefore, be considered as a review of only some of the conditions affecting the life of records.

Your attention is called to three typographical errors in this report as follows:

1. Page 571, line 1 under the heading Inks and Sensitized Coatings, the first word should be "India" instead of "Indian".

2. In the same line the words "the most part" between the two commas, should be deleted.

3. Page 571, line 2 under Par. 3, Graphite Pencils, the second word should be "unless" instead of "unles".

VICE PRESIDENT WOOLFORD: Thank you, Mr. Ludolph.

Assignment 4—Use of Statistics in Railway Engineering.

CHAIRMAN FRIEDMAN: M. C. Wolf, valuation engineer, Northern Pacific Railway, will now present the report on Assignment 4. This report was not published in the Bulletin for the reason that it will require considerably more time to complete; however, I feel that a brief progress report will be of interest to the Association.

M. C. WOLF: Mr. Chairman, fellow members and guests: Under this assignment we are studying Service Lives of Depreciable Railroad Property.

When this study was assigned, it was suggested that we might begin with depot buildings. A number of authorities have published acturial and other methods for analyzing the data for such a study, not all of which are directly applicable to such groups as long-life railway depots.

One approach which appears suitable to the present purpose starts with the analysis of retirements summarized according to the age of the property upon the date of retirement. Calculation is then made of the percentage of the surviving units at the beginning of each year of age which is retired during that year. From this the percentage of original units which is retired during each year of age, and finally the percentage surviving, are calculated. The result may be shown graphically to produce a survivor curve.

For long-life property, there seldom are sufficient historical data to produce a closed survivor curve. The ultimate retirement of the oldest surviving units is predicted by projecting the curve to the point of 0 percent survival. When there is a reasonably long historical record, the probable error of such projection can be held within reasonable limits.

We now have some data arranged to give this type of information for masonry and brick depots. A detailed study has been made of the life experience of original installations only. One dollar of original cost has been used as the study unit.

The collecting and analyzing of the data are burdensome tasks. Before seeking data from more railroads and before proceeding further with the assignment, we propose to review the progress which has been made so far, and to consider whether simplifying the calculations will produce results which are sufficiently precise.

Are there any questions?

D. B. Fleming [Pittsburgh & Lake Erie]: You have stated that published methods for analyzing the service lives of property are not always directly applicable to railroad property. Will you explain this please?

Mr. Wolf: A great deal of the published information has to do with such special methods as cycle of replacements. Of course, these were very old buildings when we started this. There has not been enough experience to use such methods. Also, on such structures as large depots, buildings or shop buildings, substantial changes and alterations, and partial retirements are made before the ultimate retirement of the unit, and these changes affect the life experience in your investment dollar.

Vice President Woolford: Thank you, Mr. Wolf.

Assignment 6—Valuation and Depreciation: (a) Current Developments in Connection with Regulatory Bodies and Courts.

Chairman Friedman: The report on Assignment 6 will now be presented by C. R. Dolan, assistant engineer, Missouri Pacific Railroad.

C. R. Dolan: Mr. Chairman, members and guests:

The report of the subcommittee mentioned the publication of the Elements of Value for Class I line-haul carriers as of December 31, 1956, and December 31, 1957, by the Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission. The Elements of Value as of December 31, 1957, were officially released January 28, 1959.

The report of the subcommittee mentioned the successful outcome of the elimination of the 30 percent depreciation reserve which was imposed upon the railroads for income tax purposes. Since the Committee 11 report was prepared, the Internal Revenue Service has issued in draft form regulations that will implement the new statute. Railroads have been making studies to determine whether or not to accept the new conditions imposed.

I would like to report on some further legislative proposals concerning depreciation which are of interest to railroads. Throughout industry there is urgent need for a realistic depreciation policy—one which recognizes not only factors of obsolescence in this age of technological advancement, but also the inadequacy of rates based on estimated lives of depreciable property ranging up to 100 years in relation to current cost of replacements. Nowhere is this more manifest than in the railroad industry. As a means of accomplishing relief in this area, the railroads advocate the enactment of legislation which would: (1) shorten the lives of railroad depreciable property; (2) authorize the establishment of a construction reserve fund for use in connection with the acquisition of equipment and other property used by the railroads; and (3) support a proposal to provide for a reinvestment depreciation deduction. While deductions are involved in each of these proposals, there is no tax forgiveness; rather tax deferral. This report is presented as information.

Vice President Woolford: Thank you, Mr. Dolan. The report will be so received.

Assignment 7—Revisions and Interpretations of ICC Accounting Classifications.

CHAIRMAN FRIEDMAN: The report on Assignment 7 will now be presented by M. M. Gerber, accounting engineer, Baltimore & Ohio Chicago Terminal Railroad.

M. M. GERBER: Mr. President, members of the Association and guests: The Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission on April 23, 1958, amended Case A-101 relating to accounting for the cost of welding rail into longer lengths, and for the retirement of track material not replaced.

This report is presented as information only.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Gerber. Your report will be so received.

Assignment 9—Simplification of Annual Reports on Form 588 to the Interstate Commerce Commission, and Underlying Completion Reports.

CHAIRMAN FRIEDMAN: H. N. Halper, valuation engineer, Erie Railroad, will now present the report on Assignment 9.

H. N. HALPER: Mr. President, members of the Association and guests:

The report of this subcommittee was endorsed by our Board of Direction for submission to the Interstate Commerce Commission jointly with representatives of the Association of American Railroads—Accounting Division.

Accordingly, we sent the report to Vice President Seder of the Association of American Railroads, who after circulating it to the Accounting Division, appointed a working committee of accountants consisting of Messrs. Broberg of the Milwaukee, Pease of the Illinois Central and Harris of the Southern. I appointed a working committee of engineers, all members of this Association, consisting of Messrs. Higgins of the Santa Fe, Restall of the Boston & Maine and Hager of the Southern.

This joint working committee met, reviewed the report and unanimously approved it with a few minor changes in phrasing. It is now with the proper Bureau of the ICC for study and review by its engineers.

Meanwhile, at the suggestion of several members of our Board and instructions of our president, the working committee continued to study the possibility of simplification of recording and reporting of track material, which was not previously covered in our report. We have made considerable progress and expect to submit a report thereon in the near future, and then submit the outline of the report for review and consideration by our Board of Direction as well as the Accounting Division of the Association of American Railroads.

This report is submitted as information.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Halper. Your report will be so received.

Assignment 10—Uses of Photography in Railroad Construction and Maintenance Work, Collaborating with Other Interested Committees.

CHAIRMAN FRIEDMAN: C. B. Martin, valuation engineer, New York Central Railroad, will now present the final report on Assignment 10.

C. B. MARTIN: Mr. President, members of the Association and guests:

Photography can assist the railroad engineer in many ways in the performance of his duties and becomes an excellent record for future reference.

Your committee has compiled a list of the most convenient types and sizes of still and movie cameras and the uses to which they can be applied by the railroad engineer in maintenance, construction, location and training.

Aerial photography, aerial photogrammetry and aerial photographic analysis are also of service to the engineer, but as this service is generally contracted for by outside parties, only the uses are shown in the report.

Since photographs are useful for future studies as well as for the purpose for which they were intended, it is the recommendation of the committee that an index be prepared of the photographs available in the various departments of the railroad. It is further recommended that the index be placed in the library, chief engineer's file, or some other central location for future reference.

This report is presented as information.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Martin. Your report will be so received.

CHAIRMAN FRIEDMAN: Mr. Vice President, this concludes the report of Committee 11. It also marks the end of my term as chairman of the committee, The job has been stimulating and rewarding, and I wish to thank the subcommittee chairmen and members for their assistance and active participation in the work, and also the officers of the Association and its secretary and his staff for their complete cooperation.

I will now introduce the officers of the committee for the ensuing term. I am sorry that the chairman, L. W. Howard, land and tax commissioner of the Chicago & Western Indiana Railroad could not be present. He will become chairman of the committee for the next term. He is not here for the reason that it was necessary for him to attend an urgent meeting on his railroad.

Our new vice chairman is M. C. Wolf, valuation engineer of the Northern Pacific Railway. [Applause]

Our secretary will continue to be B. H. Moore, assistant to vice president, Association of American Railroads. Mr. Moore. [Applause]

I am sure that they will have the utmost cooperation from members of the committee and of the officers of the Association. Thank you.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Friedman, and members of your committee, for the valuable work which you are doing for this Association and for the reports which you have presented here today.

I want to commend you particularly, as did the Board of Direction, for the effort your committee is making to bring about simplification of annual reports to the Interstate Commerce Commission on form 588, and likewise of completion reports. The recommendations which you have made in this regard will go a long way in reducing the amount of work involved in the preparation of these reports.

I want to especially thank you, Mr. Friedman, for the able manner in which you have directed the efforts of your committee for the past three years and for the splendid cooperation which has existed between your committee and the secretary's office.

We are glad to welcome as the new chairman of Committee 11, Mr. Howard, and as the new vice chairman of the committee, Mr. Wolf. I am sure they will continue the good work which has been done by your committee under your direction.

Your committee is now excused with the thanks of the Association. [Applause]

Discussion on Yards and Terminals

[For report see pp. 289–300]

[Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: The next committee to present its report is Committee 14—Yards and Terminals, of which F. A. Hess, division engineer, Indiana Harbor Belt Railroad, Hammond, Ind., is completing his third year as chairman. Will Mr. Hess and members of his committee please come to the platform and present their report.

Again we will appreciate it if the chairman, vice chairman and secretary of the committee, and all reporting subcommittee chairmen, will take places at the main speaker's table, as near the podium as possible, in the interest of conserving time in coming to the podium when called upon. And once more, I invite discussion from the floor, in connection with any and all of the reports. When using the microphones please state your name and connection for the benefit of the record. Mr. Hess you may proceed.

F. A. HESS: Mr. Vice President, members of the Association and guests:

This committee, in appreciation of the fine work that J. N. Todd, retired superintendent of scales and work equipment, Southern Railway System, has done for it, has elected him Member Emeritus.

This is the last presentation that I will conduct as chairman of Committee 14. I have enjoyed the undertaking and wish to thank the members for their wonderful cooperation. I am pleased to announce that A. S. Krefting, assistant chief engineer—bridges and structures, Soo Line Railroad, will succeed me and I know he will do a good job. Would you please stand, Art? [Applause]

Our new vice chairman will be D. C. Hastings, superintendent Potomac Yard, Richmond, Fredericksburg & Potomac Rairoad. Will you stand up, Dave, please? [Applause]

Committee 14 has six committee reports and a special feature consisting of films showing various piggy-back operations. The committee reports appear in Bulletin 546, pages 289 to 300, incl. Discussion from the floor is invited at the conclusion of each report.

I wish to thank the subcommittee chairmen and their representatives for the reports, which I know required much of their personal time.

Assignment 1—Revision of Manual.

CHAIRMAN HESS: F. E. Austerman, assistant chief engineer, Chicago Station Company, will now present the report on Assignment 1.

F. E. AUSTERMAN: Mr. Vice President, Mr. Chairman, members and guests:

Your committee offers a report on Water-Front Terminals, the recommendation that it be adopted and published in the Manual as a continuation of the material on Freight Terminals.

It will be a new section covering the tracks and facilities on the shore side of a water-front terminal necessary to load and unload freight from railroad freight cars to ships and from ships to freight cars. The subject matter will be expanded and developed further to provide a more complete section on water-front terminal facilities.

I move that this report be inserted in the Manual on page 14–3–16 as Sec. I. Water-Front Terminals.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 2—Classification Yards, Collaborating with Committee 16.

CHAIRMAN HESS: F. R. Smith, chief engineer, Union Railroad, chairman of Subcommittee 2, will present his report.

F. R. SMITH: Mr. Chairman, members of the Association and guests: Under this assignment we are now studying "Rollability of Cars."

The study of improving car rollability for better control is new and challenging. It was first presented to the Association by your committee in 1957 with the suggestion that the subject be referred jointly to the Mechanical and Engineering Divisions of the Association of American Railroads.

As a result of this recommendation, the subject was assigned to the AAR Joint Committee on Relation Between Track and Equipment. Our Research Center has circulated pertinent questionnaires to railroad chief engineers and chief mechanical officers, and related industries. All questionnaires have not as yet been returned, so no summary report can be made at this time. The subject is still active in the Joint Committee and we hope it will continue to be until many of the unknowns have been explored.

Your committee submits this report as information with the recommendation that the subject be continued in view of the need for important research.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Smith. Your report will be so received.

Assignment 4—Use and Location of Yardmasters' Offices.

CHAIRMAN HESS: R. H. Peak, Jr., division engineer, Illinois Central Railroad, chairman of Subcommittee 4, will present his report.

R. H. PEAK, JR.: Mr. Vice President, members and guests:

Committee inspection trips to new and rebuilt yards have shown the yardmaster's tower to be coming into widespread use. Your committee felt that a study of current thinking in the location and use of yardmasters' offices would be useful to inform the Association of the trends indicated by our observations.

Thirty-five offices on 14 railroads were studied. The use of towers for visibility was widespread; most of the roads on which towers are not used reported that towers would have been preferred, but the need for economy or special physical conditions prevented their use.

Along with the towers, a large increase in the variety, quantity and quality of communication facilities provided the yardmaster was noted.

The report is presented as information with the recommendation that the subject be discontinued.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Peak. Your report will be so received.

Assignment 6—Facilities for Loading and Unloading Rail–Truck Freight Equipment.

CHAIRMAN HESS: C. F. Parvin, engineer maintenance of way and structures, Pennsylvania Railroad, chairman of Subcommittee 6, could not be present, so H. J. McNally, area engineer, Pennsylvania Railroad, will present the report in his stead.

H. J. MCNALLY: Mr. Chairman, members and guests: This report is submitted as information with the recommendation that the subject be continued.

The number of facilities for handling rail-truck freight equipment is continually increasing. Our report this year brings to your attention the handling of unit containers and trailer bodies by traveling gantry crane in lieu of other types of unloading methods, such as ramp unloading, etc.

There has also been considerable development in side loading and unloading of trailer bodies with the use of standard flat cars.

VICE PRESIDENT WOOLFORD: Are there any questions from the floor? Thank you, Mr. McNally. Your report will be received as information.

Assignment 7—Parking Facilities for Patrons at Passenger Stations.

CHAIRMAN HESS: L. F. Pohl, office engineer, Chicago, South Shore & South Bend Railroad, chairman of Subcommittee 7 will present his report.

L. F. POHL: Mr. Vice President, members and guests:

The report of Subcommittee 7 on parking facilities for patrons at passenger stations is a final report presented to you as information.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Pohl. Your report will be so received.

Assignment 8—Use of Car Retarders at Locations Other Than at a Hump.

CHAIRMAN HESS: G. H. Chabot, assistant division engineer, Chesepeake & Ohio Railway, chairman of Subcommittee 8, will present his report.

G. H. CHABOT: Mr. Vice President, Mr. Chairman, members and guests:

Car retarders in the past have been located primarily at the hump end of classification yards. Within recent years these retarding devices have had more diversified applications, and their use has been expanded to various locations in yard tracks and in tracks serving private concerns.

This report is about the successful applications of car retarders at locations other than at humps. In our report we have defined the two basic types of retarders, namely, the operated retarder and the inert retarder, pointing out in each case its purpose and where it is generally found. It includes a list of some of the practical applications to date, along with the various benefits derived in each application. Finally, a table of present installations is furnished for ready reference; this table includes the type of traffic handled, the number and kind of retarders used, and the basic operation at each of the locations enumerated.

This is a final report, presented as information.

VICE PRESIDENT WOOLFORD: Are there any questions from the floor? Thank you, Mr. Chabot. The report will be so received.

CHAIRMAN HESS: Thank you, Mr. Chabot.

This committee has an added feature consisting of several films showing various forms of so-called piggy-back operations. You may have noticed in our report on Assignment 6 we referred to "facilities for loading and unloading rail-truck freight equipment." Originally, reference was made to trucks on freight cars. In some operations, as you will see from the films, only the trailer body is placed on the cars. In one instance the trailer becomes the freight car.

We have four films: the Chesapeake & Ohio's "Railvan", the Missouri Pacific's "Modern Pace in Transportation", the American Car & Foundry's "Retractable Trailer Hitch", and the New York Central's "Flexi-Van". The films show the various types of operation.

This is the American Car & Foundry's "Retractable Trailer Hitch" film. They tell me it is one of the original films they made when they were first making tests, but it does demonstrate the method of hand loading which is the more or less conventional type at this time.

[The "Retractable Trailer Hitch" film was shown.]

CHAIRMAN HESS: I think we can wind up that film and start another one. This is the Missouri Pacific film.

[The "Modern Pace in Transportation" film was shown at this time.]

CHAIRMAN HESS: Proceed with the next one.

[The "Railvan" film and the "Flexi-Van" film were shown.]

CHAIRMAN HESS: I wish to thank the railroads and industry for making the films available, Ed Gehrke for going over these films with me, and the projector operator for his wonderful assistance.

I also wish to thank the men from Committee 11 who volunteered to man the microphones.

Mr. Vice President, this concludes the reports and special feature of this committee.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Hess and members of your committee for the informative report you have presented and the trouble to which your committee went to show the interesting, informative films of various types of rail-truck freight equipment being used.

I might say here that your special feature was most interesting, I am certain, to the whole Association. One subject which is very alive in the Association—it certainly will be this year—is standardization. I think we have too many kinds of piggy-back equipment and undoubtedly the matter of standardization will apply here also in a few years so we won't have so many different types.

Thank you, Mr. Hess, for the able and dedicated leadership which you have given to Committee 14 for the past three years. As you lay down your responsibilities in this regard, we are pleased to welcome as your successor, Mr. Krefting, and as the new vice chairman of your committee, Mr. Hastings. We are satisfied that under their direction the good work of your committee will continue to move forward.

Your committee is now excused with the thanks of the Association. [Applause]

Discussion on Economics of Railway Location and Operation

[For report see pp. 209–244]

[Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: We will next hear from our Committee 16—Economics of Railway Location and Operation, the chairman of which is R. L. Milner, staff assistant to chief engineer, Chesapeake & Ohio Railway, who is completing his second year as chairman of this committee. I shall be pleased if Mr. Milner and members of his committee will come to the platform and present their report.

As in the case of the previously reporting committees, I would ask that Mr. Milner and the vice chairman and secretary of the committee take their places at the main speaker's table, immediately to my left, along with all reporting subcommittee chairmen, and for the benefit of those who may have just come into the room, I would repeat that the privilege of the floor is granted to you to comment on any or all of the reports of the committee. Those manning the aisle microphones will be glad to make them available to you for this purpose.

In using the microphones please state your name and the carrier with which you are associated. Mr. Milner, I am pleased to turn the meeting over to you.

CHAIRMAN R. L. MILNER: Mr. Chairman, members of the Association and guests:

During the past year your committee lost one of its valued members, Allen Hazen, assistant engineer of the Chicago, Milwaukee, St. Paul & Pacific Railroad. A memoir prepared by I. C. Brewer, H. B. Christianson, Jr., and T. C Nordquist will be published with this report in the 1959 volume of the Proceedings.

MEMOIR

Allen Hazen

Allen Hazen, assistant engineer in the assistant division engineer's office of the Chicago, Milwaukee, St Paul & Pacific Railroad at Minneapolis, Minn., was born in Dobbs Ferry, N. Y., August 21, 1917. He died on October 20, 1958, at the age of 41, and is survived by his wife, Lenore, daughter Rebecca, and two sons Allen and David.

He attended Dartmouth College, graduating in 1939. In 1940 he obtained a C.E. degree from Dartmouth's Thayer School of Engineering.

Mr. Hazen's entire career was spent in railroad service. After previous service with the Pennsylvania Railroad, followed by ten years with the Maine Central, he served from 1951 until the time of his death with the Milwaukee Road.

Mr. Hazen became a member of the AREA in 1947 and served on Committee 16 from 1953. Active on all committee assignments, he had an intense desire for the advancement of railroading. He was a member of the Minnesota Society of Civil Engineers, the Valley Community Presbyterian Church, and the Compass Masonic Lodge 265.

Committee 16 on behalf of the American Railway Engineering Association wishes to extend to Mr. Hazen's family its sincerest sympathy and appreciation of its association with him over the years.

CHAIRMAN MILNER: Your committee is reporting on 7 of its 11 assignments. These are presented on pages 209–224, Bulletin 546. One of these is a final report, submitted as information, while six are progress reports. Your committee invites your comments regarding its presentations and will be glad to reply to any questions raised thereon.

Assignment 2—Effect of Degrees of Curvature on Cost of Track Maintenance, Collaborating with Committees 4 and 5.

CHAIRMAN MILNER: Our first report is on Assignment 2, and will be presented by Subcommittee Chairman L. P. Diamond, assistant engineer—research, the Chesapeake & Ohio Railway Company.

L. P. DIAMOND: This is a progress report on the analyses of the costs attributable to track curvature, with special reference here to the costs lodged against ICC Accounts 218—Ballast, and 220—Track Laying and Surfacing. These analyses are a portion of individual studies regarding the effects of track curvature on Account 212—Ties, Account 214—Rail, Account 216—Other Track Material, Account 218—Ballast, and Account 220—Track Laying and Surfacing.

For an idealized track section, employing AREA standards, the percent increase in ballast required to raise superelevated track as against tangent track may be calculated. Such a theoretical determination might be used to determine the influence of curvature on ballast material costs in Account 218.

However, a mathematical multiple regression analysis was performed on actual volumes of ballast applied to differing types of railroads over a period of years, which indicates that under usual operating conditions other factors are so influential as to overpower such a theoretical expectation. These other factors that might exert an influence in determining the volume of ballast required in repairs to tracks are, among others, roadbed stability, ballast subsidence, smoothing and cribbing.

In Account 220 there is a similar situation which prevents a simplified approach in determining the effect of track curvature on costs. Account 220 includes the cost of labor in applying ties, rails, other track material, and ballast. The corresponding material costs

are lodged against Accounts 212 through 218. In addition, Account 220 contains labor costs attributable to alining, surfacing, gaging, shimming, restoration of track after accidents, bolt tightening, etc., which costs constitute the major portion of this account.

Consideration of a recent study of the relationship between costs in Account 218 and Account 220 illustrates that even a moderate detailing of some of the factors involved in primary account costs is not sufficient to permit only the use of primary account totals in determining the effect of curvature on the cost of maintaining track.

There isn't sufficient information available when only the factors of ballast type, railroad division, and traffic load per mile are taken into consideration in seeking a relationship between the costs in Accounts 218 and 220. By convention, there are many other costs in Accounts 218 and 220 totals that mask the relationship between cost of ballast dumped and the cost of labor to apply it properly to track. A mathematical analysis of covariance was performed to demonstrate the validity of these remarks.

Differing accounting practices among the railroad companies present further complications in the use of primary account totals to meet the objectives of this assignment. For example, differing salvage values of rail may be credited to Account 214—Rail, sometimes with a distinction between relay rail and scrap, sometimes not. Also, in Account 218 differing local practices might allocate differing proportions of a given size of ballast raise to capital and to operating cost.

Accordingly, a more detailed breakdown of the costs in Accounts 212 through 220 is now underway in order to determine the effect of curvature on both labor and material costs. Samples of sufficiently detailed costs have been obtained from three railroads and are now under study. Analyses of these data will be presented in a future and final report on this assignment.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Diamond. Your report will be received as information.

Assignment 3—Determination of Maintenance of Way Expenses for Various Traffic Volumes, Collaborating with Committee 11.

CHAIRMAN MILNER: Our next report is on Assignment 3—Determination of Maintenance of Way Expenses for Various Traffic Volumes. It will be presented by Subcommittee Chairman James P. Ray, regional engineer, Baltimore & Ohio Railroad.

J. P. RAY: I do not know of any better comment to make on the report of progress made by this subcommittee than the opening paragraphs of the published report. It must be emphasized that this is a progress report, not a final report, and further emphasized that comment and criticism of the method outlined by that progress report are invited.

Committee 11 is collaborating with us in analyzing this problem. Certain inaccuracies in the printing of the report have been called to our attention. Appropriate action will be taken toward making the necessary corrections at the earliest possible moment.

It is also desirable to call your particular attention to the last part of the report under the heading "Comment on Use of Experience Method of Determining Normal Maintenance Expense." In that section it is set forth that we have attempted only an outline and approach to the problem and that we are not attempting to derive a never-changing universal formula. It is my personal conclusion that such a formula cannot be found. There has been a suggestion that the committee recognize that competent statisticians might want to employ more refined statistical techniques than those suggested in this report. However, the report suggests methods that seem to be the best that can be reasonably handled by people without advanced statistical training.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Ray. Your report will be received as information.

Assignment 4—Potential Applications of Electronic Computers to Railway Engineering and Maintenance Problems in Research, Design, Inventory, Etc., Collaborating with Committees 11 and 30, and Informally with the Railway Systems and Procedures Association.

CHAIRMAN MILNER: The next report is on Assignment 4 by Subcommittee Chairman Ferdinand Wascoe, manager, Bureau of Transportation Research, Southern Pacific Company.

FERDINAND WASCO: Thank you, Mr. Milner.

Mr. Vice President: This is a progress report on the potential applications of electronic computers to railroad engineering and maintenance problems. The report lists available equipment and estimated initial installation costs along with programs of engineering problems which have already been developed.

A primary purpose of this report is to stimulate the interest of railroad maintenance engineers in the help that modern electronic data processing can give them in the solution of their present problems as well as open new vistas in the handling of problems which they previously could not economically consider.

The greatest task of this subcommittee remains for the future. It is in the area of developing a library of engineering programs, which will be available to all railroad engineering departments. The next and last logical step will be to work toward making the programs of the various computer systems interchangeable.

VICE CHAIRMAN WOOLFORD: Thank you, Mr. Wascoe. Your report will be received as information.

Assignment 7—Engineering, Maintenance and Operating Benefits to be Derived from Increased Joint Use of Railway Facilities, Collaborating with Committees 11, 14, and 20.

CHAIRMAN MILNER: The next report is on Assignment 7. It will be presented by Subcommittee Chairman J. W. Barriger, president, Pittsburgh & Lake Erie Railroad.

J. W. BARRIGER: Mr. Chairman, members: Your Subcommittee 7 submits a progress report on the benefits from increased joint use of railway facilities. As pointed out in a special presentation last year and in this report, there are thousands of joint facility contracts in effect throughout the country, and yet the possibilities for new coordination projects are virtually unlimited. We, therefore, commend to the railroad managements the task of further exploration to determine the benefits that may accrue from improved service and economy in administration, maintenance and operation of railroad properties. We hope to be able to follow this report with specific examples of the progress which has been accomplished during recent years, but in the meantime respectfully suggest a review of the possibilities for your particular railroad. The political climate for coordination and consolidation is better today than in the past 40 years, and the urgency for economic measures is greater than ever.

Thank you very much. I remain for questions if there may be any.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Barriger. Your report will be received as information.

Assignment 8—Inovations in Railway Operations.

CHAIRMAN MILNER: The next report is on our Assignment 8, to be presented by Subcommittee Chairman A. L. Sams, principal assistant engineer, Illinois Central Railroad. Mr. Sams.

A. L. SAMS: Mr Chairman, members and guests of the Association: This might be called the subcommittee on daydreaming We have taken a good look at several operat-

ing and engineering problems in railroading today and have suggested a solution that may be forthcoming. This is a progress report, presented as information. If any members of the Association have suggestions along the lines of this assignment we would be happy to receive them for inclusion in future reports on this subject.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Sams. Your report will be received as information.

Assignment 9—Economics and Methods of Utilizing Railway Property, Right-of-Way, and Facilities to Develop or Increase Secondary Sources of Railway Revenue.

CHAIRMAN MILNER: The next report is on Assignment 9. It will be presented by Subcommittee Vice Chairman J. W. Bolstad, chief engineer, Ft. Dodge, Des Moines & Southern Railway, in place of F. J. Corporon, who is not here today. Mr. Bolstad.

J. W. BOLSTAD: Thank you Mr. Milner. Mr. Vice President:

This is a final report, presented as information. The complete report can be found on page 237 of Bulletin 546. The ideas have been listed without detailed discussion thereof and are grouped under general classifications as follows:

Executive, financial and legal; real estate and taxation; personnel; public relations; research and development; accounting; traffic; operating; purchasing, stores and insurance; mechanical; engineering; bridges and roadway; communications and signals; and miscellaneous.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Bostad. Your report will be received as information.

Assignment 11—Review of Developments in New Methods and Modes of Transport.

CHAIRMAN MILNER: The next report of the committee is on Assignment 11. It will be presented by Subcommittee Chairman Frank J. Richter, publisher, Modern Railroads Magazine. Mr. Richter.

F. J. RICHTER: Mr. President, Mr. Vice President, members: Our assignment is a little bit like Mr. Sams' Assignment 8 in that we are charged with doing a little dreaming. Ours is supposed to be primarily outside of the railroad industry rather than within it. This is the first report to be prepared and presented by this subcommittee, and we hope that there will be a series of other reports forthcoming in other years about new methods and new modes of transportation that are beginning to make their appearance on the horizon, and which may some day become railway competition or offer possibilities as adjuncts to railway operations.

The report itself appears on page 240 of Bulletin 546. It goes into the actual system of conveying suspended solids by pipeline, the nature of the applications that have already been made, advantages and disadvantages of this particular type of operation, and discusses the application of that particular type of transportation compared with railroad operation.

I would like to read a paragraph of the report because of the possibility that this type of operation does hold.

"In situations where a limited amount of material is to be moved each year, solids pipelines can offer serious competition to the railroads. Over-all pipeline costs are likely to be well below the fully allocated costs of rail transportation, particularly in a situation where no railroad yet exists. Where a parallel rail line does exist, however, fully allocated pipeline costs could well be higher than the marginal (i.e. out-of-pocket) cost of railroad movement."

The conclusions of this particular report are somewhat obvious. If railroads can reduce their out-of-pocket operating costs, and if they are permitted to price their services on this basis, then solids pipelines may not pose any serious competitive threat. The exception to this will be only in the case of new routes where the traffic volumes are too low to justify railroad construction.

Today, of course, railroad out-of-pocket costs are still quite high, and marginal pricing is frequently prohibited by the ICC, so the development of solids pipelines cannot be ignored.

That's about the essence of our report, Mr. Chairman.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Richter. Your report will be received as the first of a series of reports on this assignment.

CHAIRMAN MILNER: I would like to add that considerable progress has been made on the four other assignments on which we are not quite ready to submit reports.

I take this opportunity to thank and commend the members of the committee for the exemplary work they have performed during the past year.

While this concludes the formal submission of reports by your committee, we have one more presentation. This is a special feature on the subject "Economics of Railway Engineering".

The member of our committee whom you have just seen will discuss this subject. He has evidenced keen interest in this subject through his many fine, incisive editorials.

Gentlemen, I again present Frank Richter.

The Economics of Railway Engineering

By Frank Richter

Executive Vice President and Publisher of Modern Railroads

I am certainly appreciative to Committee 16 for giving me the opportunity to express some of my own viewpoints about this particular subject. When I saw the program, though, I was a little disconcerted because it seems that some of the stars on the program have or are going to speak in very much the same area that has been assigned to me. For example, Mr. Loomis talked this morning about "Change and Challenge in Railroad Engineering." Tomorrow Mr. May is going to talk about the "Engineer's Responsibility to Railroad Management", and then Mr. Heineman at our luncheon is going to talk about "Railroad Economics Today."

That made we wonder a little bit: where does that leave me? I went over my thoughts a little more closely as a result. I feel that what I am going to say to you gentlemen right now might complement the thoughts of the other three men. Actually, I am not going to talk primarily about the economics of railway engineering. What I would like to present to you are some thoughts on the human side of the economics of railway engineering.

The reason why I think that is so important at this time is because when we look at all of our activities, all of the activities of other people, we can see that nowhere today can one separate man from his environment.

Moreover, every environment is subject to the great personality differences that are inherent in human nature. Hence, one cannot speak realistically about the economics of railway engineering without reckoning with the human side of it.

The engineer's environment is engineering knowledge. In practical application,

though, the engineer must recognize the *particular* environment in which his engineering knowledge is going to be applied. That superimposes upon engineering knowledge *economic* knowledge and analysis. Then a third factor enters—the engineer's responsibility as a manager and a risk taker.

Thus entereth that all-important element: the *human side* of the economics of railway engineering.

It is probably natural that I, as a member of one group within the American Railway Engineering Association, should come to observe this facet of railroad engineering department work. Remember, Committee 16 is a committee on the *economics* of railway location and operation. While engineering-oriented in its own approaches as an AREA group, it is *economics*-oriented as a committee. It looks into existing premises and newer ones not only from the standpoint of whether they work, but also how each compares with existing norms and what its potential may be.

Now, if any group of railroad officials is engineering-oriented, it should be you gentlemen. That's so obvious, it hardly need be mentioned. But I do so for a purpose.

At the same time as you are so strongly engineering-oriented, far more of the day-by-day responsibilities of most of you are of a non-engineering nature.

It is as much in the management phases of railroad engineering work as any other that your own future, that of your railroad, and that of the entire railroad industry lies.

Many of you men have management responsibilities over organizations that are much larger than some of the best-known business organizations in the country—companies whose products are bywords in every household in the nation.

The engineering department of a typical large railroad numbers 10,200 people. Last year, it spent $75 million on maintenance of way and structures.

A medium-sized road numbers about 3500. Last year, it spent $32 million for engineering maintenance and improvement.

A typical small-sized one has a payroll of 600 people in its engineering department; it spent $4½ million in 1958.

It takes a lot of skill to manage that many people effectively and spend that much money judiciously. While knowledge of engineering is an essential, the managerial and supervisory ability of many men becomes the real determinent of how well each railroad performs.

On railroad after railroad, expenditures are made—and employes go about their work—according to patterns that have evolved over the years. That system has been and is today a very creditable one. But in terms of most effective supervision, training, work relations, and spirit, it does not make the most of what have become the skills and principles of management.

Railroads are now at a point, as a highly competitive industry, where a thorough, realistic look at *management* practices is very much needed. For each of you, this should mean examining most critically the very system which brought you to your present positions—and even more important—the very systems you now practice as your own management methods.

Railroad engineers start off their careers with an excellent foundation upon which to build management skills. Yet, they generally have two handicaps to overcome.

Engineering students—and particularly the most promising ones—have a passion for their engineering subjects. They literally eat them up. Often they consider other non-engineering subjects as a necessary nuisance.

Among those who do start out on engineering work the ones who get most immediate recognition for their engineering work obviously are those who are strongest in engineer-

ing work (otherwise they might quickly move into transportation or traffic). As these men mature, gain more experience, and move up the ladder in the Engineering Department, they take on more and more responsibilities. The following then becomes increasingly important:

—the engineer as a manager,
—the engineer as an economist,
—the engineer as a risk taker.

Yet, how much conscious effort is made to inculcate knowledge of these skills? Once you leave school, such skills are acquired largely by what is roughly the apprentice system of learning from others who have the greater experience. To be sure, that has merit; but it involves many pitfalls. And that is particularly true of a form of management like yours which is not management-oriented.

This isn't anything that is peculiar to the railroad industry. Just listen to a passage in the January-February issue of Harvard Business Review. It is part of a most absorbing article entitled "The Managerial Mind."

"Philosophers of science," observes this article, "tell us that scientists have a distinct 'innate prejudice' for selecting only those facts in the environment which can be *measured.*

"The quantitative attitude," it continues, "satisfies two important needs of the scientist. It helps him to be objective, and it enables him to 'prove' his relationships or laws—for instance, what will happen to 'X' units of 'Y' variable if 'B' variable changes by 'Z' units."

That, in fact, expresses some of the approaches that Committee 16 definitely must apply to AREA work. You can see it in several of the reports just presented here.)

"This mathematical predisposition," continues the article, "can also be of value to the executive (which is what you railroad engineers also are). It can result in improved ways of doing things. The budget is an example, as are standard costs and financial ratios. . . .

"Unlike the scientific mind, however, the managerial mind can admire the beauty and preciseness of measurement only up to a point. Otherwise, the decision maker may delay things while the patient dies, the war is lost, or the firm misses its opportunity. Business organizations (and let's not forget that's what railroads are) may need certain people who are deeply, zealously interested in *quantification.* But the one who receives quantitative facts and has to incorporate them into judgmental actions in a limited time should not possess this temperament in excess degree.

"Quantification," as the Harvard Business Review terms it, hardly lends itself to managing people. Yet, to show you how complex is the business of managing people, consider how many of the management specialists themselves have fallen for quantification—through their personality profiles; aptitude tests; and point systems for judging, paying, and promoting people. Some of them have fallen into the trap of trying to reduce the all important human side of personnel work to a formula.

The management problems of chief engineer, engineer of maintenance, division engineer are compounded by the complexity of conditions that are ever present. Your departments use complex equipment and work procedures. What production lines there are "move" while the work stands still—just the opposite of the type of production work managed by an engineer in a manufacturing plant. And they're spread out all over the countryside. That adds another dimension to management—the management of moving, housing, and scheduling.

When conscious effort has been made in recent years to consider such work as management, the result has been some might dramatic shifts in railroad engineering department work approaches.

Some railroads have included engineering officials in postgraduate type management training which they have instituted. These intensive four- to eight-week courses bring into the man's stream of consciousness principles that do not appear in the engineering schools or in work experience. Even without the opportunity to participate in such courses, the railway engineer can familiarize himself with this vital aspect of his work. He can get and read some of the highly informative, well organized management books that have been published.

I have heard enough railroad officials belittle both the courses and the books to say this: Certainly, the courses and books deal in a lot that is already known to each of you. I'd hardly expect you to have reached your present position in a railroad without having learned a lot of that by experience and association. Dividends do come, though, from realizing that sandwiched in between what is known is very much that is not known. And *that* can be studied to your benefit and advantage!

Partaking of that can have the same effect in better equipping the engineer as a manager as taking a set of golf lessons from a pro can help your golf game.

These observations are as fresh in my mind as any; for I have just completed reading a book called "Principles of Management—an Analysis of Managerial Functions." The second edition of this book has just come out. It dwells upon many of these very aspects of management which I have merely touched upon here. Moreover, one of its authors, Harold Koontz, writes with an understanding of railroad management. He was assistant to Judge Fletcher when he was Vice President—Research of the AAR; chief of the Traffic Branch of the War Production Board; and a consultant of the Sante Fe. He is now Professor of Business Policy and Transportation at the University of California.

When preparing my notes for this analysis, I was tempted to quote extensively from this book of Koontz and O'Donnell. One of the reasons for that is because it is so full of down-to-earth analysis of a lot of this management business.

It does not promise that anyone can become a topnotch manager in six easy lessons. It recognizes the value of scientific methodology as the foundation for sound management. But just as scientific methodology *must* be learned by the engineer, many of the principles of management also *can* be learned. And this book is as good a starter—or refresher—as any. Even the very top executives can gain a lot by reading and studying such works.

Now to my second point—the railroad engineer is an economist.

The railroad engineer has proved himself a good economist in terms of the definition made by A. M. Wellington, the distinguished American engineer. Back in 1885, he said, "It would be well if engineering were less generally thought of, and even defined, as the art of constructing. In a certain important sense, it is rather the art of not constructing; or to define it rudely but not inaptly, it is the art of doing that well with one dollar which any bungler can do with two after a fashion."

There's a lot of meat in that. Yet, there's another side of the coin.

Let us not overlook that Wellington made his famous $1 instead of $2 observation with the reservation that this is true "in a certain sense."

Economics is more than merely finding ways of gettings things done at less cost, as important as that is. Many of the present-day engineering department advances in productivity and a more durable "plant" require a higher initial investment. The machines require more dollars initially. The railroad manager as an economist needs an open

mind to study carefully the potentialities of newer ways or machines. Appreciation of the economic principles involved can nurture an even more well-rounded engineer-manager than adherence to Wellington's "I can do it for less" theory *alone*.

The world about us is changing at a fantastically rapid pace. There has been a great inflow of technology. Patterns of work have been affected by that and the changing work relations in all commerce. Finally, the kind of competition railroads must now cope with from other carriers puts a different perspective on much railroad engineering work.

All three of these factors, in turn, put a great strain on the railroad engineer. Hence, many economic principles need to be carefully re-examined and reappraised. Reappraisal is also necessary for many engineering formulas that are based upon conditions that no longer exist, relationships that have changed, or the possibility of using newer measuring and control techniques.

Many of the committees of the AREA, incidentally, also must face up to this problem.

In that sense, the railroad engineer—acting as a businessman—is compelled to act as an economist just as any other successful business man does.

That brings me to the third characteristic of the railroad engineer—the railroad engineer as a risk taker.

When discussing this over-all subject with Dr. L. K. Sillcox, a fellow member of AREA's Committee 16, he observed pungently, "you get what you accept. Railroads need men who fuse the economics with the practical to tell them what they can afford to accept in this day and age.

"Forward planning," he continued, "is the most needed element in railroad administration. That is needed rather than doing business by measuring against dead statistics."

The railroads have a heritage as risk takers. This is particularly true of the engineer. Does he have his counterpart today? I would say "yes." His counterpart is the man—or men—amongst engineering department officials who combine the attributes of business executive, engineer and economist—but add one mighty important characteristic—that of "chancing" innovation. He first considers its potentialities with an open mind. (You never know from whence the next "big" advance will come.) Then he lends support to try it out in a limited way. (The risk becomes a little riskier. Here he does apply positive economics.) Finally, he sticks his neck out *and presses for its use* as a standard procedure. He does it time after time. He doesn't necessarily wait to see what happens in work being done by other risk takers.

I am not talking about foolhardy risks. Rather, it is "risks" that combine business instinct with shrewd analysis of the economic advantage of really moving in on something that demonstrates a great potential.

The gifted can improve their leadership roles; the not-so-gifted can improve theirs materially by becoming more conscious that the railroad engineer is more than an engineer. He is also a business man, a manager. An appreciation of that is fundamental to a positive approach to today's economics of railway engineering—with all its opportunities to embrace advances in railroad technology.

The better trained the engineer is as a manager, the better qualified he will be to appraise the soundness of future moves which hold great potential for improving the railroad plant and railroad efficiency.

The better trained—also—will he be to help, direct, and inspire others in railroad engineering departments to carry out such work.

And the better organized will railroad engineering departments be to cope with the ever faster pace of living and transportation.

This is a mighty big and a mighty important subject to delve into in such a short time. I am profoundly grateful for being given this opportunity to touch upon it ever so lightly. I hope I have inspired you to give it even more serious thought; for it is as much in terms of *management* as any other aspects of railroad engineering work that your own future, that of your railroad, and that of the entire railroad industries lies today.

Thank you very much. [Applause]

CHAIRMAN MILNER: Thank you, Mr. Richter, for this new perspective, this fresh look, this most informative talk on a subject that is so timely and so important to us all in an era when we are so preoccupied with engineering and technological events and the problems brought about by rising costs.

That concludes the presentation of the committee, Mr. Vice President.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Milner, for another series of most interesting, informative and well-prepared reports.

I want also to thank Mr. Richter for such a wonderful talk, with the emphasis on economics, which, as you all must agree, is something we must never lose sight of in anything we do.

Mr. Milner, your committee is excused with the thanks of the Association. [Applause]

[President Meyers resumed the chair.]

Discussion on Waterways and Harbors

[For report see pp. 331–339]

[President Meyers presiding]

PRESIDENT MEYERS: The next committee to make a report is Committee 25—Waterways and Harbors, the chairman of which is F. B. Manning, engineer bridges and structures, Northern District, Chesapeake & Ohio Railway, Detroit, Mich. Due to illness, Mr. Manning could not be with us today.

In the absence of the chairman and vice chairman, Allen Sams, who was on this program previously and a recent past chairman of this committee, and who is principal assistant engineer of the Illinois Central, will present the committee's report.

Mr. Sams, will you proceed now?

ALLEN SAMS: Thank you, Mr. Meyers. I thought last year when my term of chairmanship was up, I wouldn't appear on this rostrum in behalf of Committee 25 again, but when Mr. Manning was unable to attend today and the vice chairman, Mr. Piper, had to leave early, I was glad to occupy this front seat while the Committee on Waterways and Harbors makes it report.

The report of the committee is published in Bulletin 547 starting on page 331. We are reporting on three of our six assignments. After each subcommittee report is presented, we would like to have any comments or questions on these subjects.

Assignment 3—Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation.

Mr. SAMS: The report on Assignment 3 will be made by M. A. Michel, assistant to chief engineer, Pittsburgh & Lake Erie Railroad, and chairman of the subcommittee. Mr. Michel.

M. A. MICHEL: Mr. President, Mr. Chairman, members and guests: In continuing

this committee assignment, five additional items not previously reported to the Association have been included in this year's report, which is presented as information.

PRESIDENT MEYERS: It will be so received.

Assignment 6—Planning, Construction and Maintenance of Rail-Water Transfer Facilities.

MR. SAMS: G. W. Mahn, Jr., assistant engineer, Illinois Central Railroad and subcommittee chairman, will present the report on Assignment 6.

G. W. MAHN, JR.: Mr. President, members and guests: The assignment is so broad in scope that it was felt that proper coverage could not conveniently be given the subject in one report. Your committee, therefore, limited its study this year to a facet not too often considered in a discussion of rail-water transfer facilities, that is, the facilities necessary to transfer railroad cars to and from car floats, car ferries and trainships. While this report is concerned primarily with a discussion of existing installations, it is felt that it contains material of value to members of the Association in view of the anticipated expansion of train-ship operations.

This report is presented as information.

PRESIDENT MEYERS: Thank you, Mr. Mahn. It will be so received.

Assignment 7—Relative Merits and Economics of Construction Materials Used in Water Front Facilities.

MR. SAMS: The third and last report is on Assignment 7. This report will be made by J. J. Tibbits, office engineer, Erie Railroad, in the absence of Shu-t'ien Li, chairman of the subcommittee. Mr. Tibbits.

J. J. TIBBITS: Mr. President, members and guests: This selected bibliography on the adverse effects of the environment on, and preservation of materials used in water-front facilities has been compiled from the Engineering Guide, Readers Guide and several random indices and lists of the Georgia Institute of Technology for the period from 1951 to 1958

The titles included in the bibliography are selected from descriptions given in the indices. Altogether there are 87 titles, classified for easy reference.

This is a progress report presented as information.

PRESIDENT MEYERS: Thank you, Mr. Tibbits. It will be so received.

MR. SAMS: Mr. Meyers, this concludes the report of Committee 25. In addition to the three assignments reported on, we have made some progress on the other three assignments. Before we leave the rostrum, I would like to thank the members of Committee 16 who are manning the microphones for us.

That concludes our report.

PRESIDENT MEYERS: Thank you, Mr. Sams.

I know a report such as the last one presented requires a lot of research work, and we recognize that. I am sure that many of our members will have occasion to use it.

We appreciate your standing in for Chairman Manning, and Vice Chairman Piper, neither of whom could be here. We are fortunate during emergencies such as this, although they don't arise very often, because there always seems to be a competent person that can step right in. We appreciate the reports which your committee has developed during the past year. The committee is now excused with the thanks of the Association.

This completes the reports of our committees for today, but before adjourning the meeting, I would like to announce that J. E. Wiggins, Jr., engineer water supply,

Southern Railway System, Washington, D. C., has been appointed by your president as chairman of the Tellers Committee to canvass ballots cast for the officers of the Association for the coming year. The ballots will be counted in the Gold Room on the first floor tomorrow morning, beginning at 9:30 am, looking to announcing the names of the successful candidates at the Annual Luncheon tomorrow noon.

You will probably be interested in the registration up to 4 o'clock this afternoon—486 railroad men, 499 others, making a total of 1285 who have registered up to this time.

The meeting is now adjourned and will reconvene tomorrow morning promptly at 9 am in the George Bernard Shaw Room, which is one floor below the lobby near the Randolph Street entrance.

[The meeting recessed at 4:50 o'clock.]

Tuesday Morning Session—March 10, 1959

[The meeting convened at nine o'clock in the George Bernard Shaw Room, President Meyers presiding.]

PRESIDENT MEYERS: The meeting will please come to order. It is important that we start on time because we have an intensive program this morning with six committee reports and one feature address to work in before our Annual Luncheon at noon. It is also going to be important that committees keep within the time allotted them, while in each case allowing a few minutes for any comments or discussion from the floor. We again have manned microphones in the aisles which will be brought to anyone wishing to comment. When addressing the chair from the floor, please use these microphones and begin by stating your name and your company.

Discussion on Cooperative Relations with Universities

[For report see pp. 595–631]

PRESIDENT MEYERS: The first committee to report this morning is Committee 24—Cooperative Relations with Universities, of which W. H. Huffman, assistant chief engineer, Chicago & North Western Railway, Chicago, is chairman.

If there are any additional committeemen who are not already at the speaker's table, I wish they would come up at this time.

Mr. Huffman, you may proceed.

CHAIRMAN W. H. HUFFMAN: Mr. President, members, and guests:

The report of Committee 24 this morning will consist of brief reports by subcommittee chairmen covering work accomplished during the past year.

Before proceeding with the presentation of our reports, Committee 24 wishes to express its sorrow at the passing of two valued members during the past year.

Armstrong Chinn passed away on August 28, 1958, at St. Louis, following surgery. His entire career was in the railway industry, starting with the Chicago, Burlington & Quincy Railroad in 1916. He was chief engineer of the Alton in 1929, advancing to chief executive officer in 1945, the position he held at the time of his election in 1946 to the presidency of the Terminal Railroad Association of St. Louis. Mr. Chinn joined this Association in 1920, was very active on several committees, including Committee 24, and was elected president of the AREA in 1947.

Fred Justin Lewis passed away on January 4, 1959. At the time of his passing he was dean, School of Engineering, Vanderbilt University, located at Nashville, Tenn.

He was a graduate of the University of Maine, joined the AREA in 1946 and served on this committee since 1949.

Members of Committee 24 sincerely regret the untimely passing of these two illustrious men and will miss their pleasant and friendly association with them.

The committee reports for this year can be found in Bulletin 548, commencing on page 595.

Assignment 1—Stimulate Greater Appreciation on the Part of Railway Managements of: (a) The Importance of Bringing into the Service Selected Graduates of Colleges and Universities, and (b) The necessity for Providing Adequate Means for Recruiting such Graduates and of Retaining Them in the Service by Establishing Suitable Programs for Training and Advancement, and (c) The Use of the Best Techniques and Methods for Recruiting College and University Students, These to Be Set Forth in a Guide.

CHAIRMAN HUFFMAN: I would like to call on J. F. Davison, assistant to system chief engineer, Canadian National Railways, who will give his report on Assignment 1, Mr. Davison.

J. F. DAVISON: Mr. President, members, and guests:

Under part (c) of its assignment, Subcommittee 1 submits a Student Recruiting Guide, which is printed in Bulletin 548. For those who may be interested, it is expected that reprints will be made available at a later date.

The need for a Student Recruiting Guide arises from the intense competition for graduates from engineering colleges and the resultant organizations which the universities have been forced to establish in order to bring representatives of industry into personal contact with the students. To fulfill their function, the university placement offices require certain information, and if railroad representatives expect a courteous reception, they must be prepared to cooperate fully.

Sec. A of the report outlines the relations which should be established with the university and with the potential candidates. This subject was considered sufficiently important by the American Society for Engineering Education that it sponsored the preparation of a code of ethics which was published in the December 1957 issue of the Journal of Engineering Education. This code of ethics is embodied in the recruitment guide.

Secs. B and C of the recruiting guide provide information to assist in selecting and training your representatives in interview techniques. The importance of selecting suitable representatives and giving them proper training cannot be overemphasized, as in the eyes of the student he not only represents your railroad, but to some degree at least, the whole railroad industry.

Sec. D of the guide covers the use of standard interview procedures as a means of assisting the interviewer in evaluating candidates and Sec. E provides information to assist in selecting those most suitable for railway employment. The guide concludes with comments concerning the management attitudes most likely to make your company attractive to the newly graduated engineer.

CHAIRMAN HUFFMAN: Thank you, Mr. Davison. I received advice just this morning that the Board approved the publication of this Student Recruiting Guide in reprint form, and each chief engineering officer of Member Roads will receive one of these reproductions in the very near future. Personally, I think it is an excellent guide, and I hope that all the recruiting officers of the railroads use it.

Assignment 2—Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure by: (a) Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities, and (b) Presenting to Students and their Counselors a Positive Approach to the Attractive and Interesting Features of the Railroad Industry and the Advantages of Choosing Railroading as a Career.

CHAIRMAN HUFFMAN: Our next report was to have been given by Professor B. B. Lewis of Purdue University, but about 30 min ago I received a call from him indicating that he was snowbound and would not be in the act. Of course, there are a lot of us that could have been in the same position and a lot that aren't here are in the same position. Professor Lewis is chairman of Subcommittee 2, which deals with the stimulation among college and university students of an interest in the science of transportation and particularly getting them interested in railroad work. The committee has been active during the past year, and members of Committee 24 did visit many universities during the year. We know that considerably more attention can be given to this phase of the work, and we hope that others in the railway engineering field do visit the schools. It is really surprising how well these visits are received.

As you all know, we have a set of slides that was developed a couple of years ago. There are very few students who know anything about railroad work at all, and they really get a charge out of seeing them.

Assignment 3—The Cooperative System of Education, Including Summer Employment in Railway Service.

CHAIRMAN HUFFMAN: Our next report, on Assignment 3, will be given by Professor W. A. Oliver of the University of Illinois, in place of Professor E. I. Fiesenheiser, Illinois Institute of Technology, who was unable to be here. Professor Oliver.

W. A. OLIVER: Assignment 3 has to do with the cooperative system of education, including summer employment in railroad service.

In March 1958 questionnaires were mailed both to railroads and engineering colleges throughout the United States, the purpose being threefold, as follows:

1. To determine the extent of cooperative work-study programs now in effect.

2. To determine some facts regarding the railroad industry's support of higher eduaction, and

3. Specifically, the supply and demand with regard to railroad jobs available to students during the summer of 1958.

The unusual and enthusiastic response to the survey by many railroads and colleges is evidence of the sincere desire for cooperation along certain lines. Data concerning summer jobs available were immediately tabulated and distributed to the engineering colleges on May 5. As a result, many students obtained their first introduction to railroad work, and without question, some of them have become prospective future employees.

We intend to continue the procedure of last year of posting job opportunities at engineering colleges as one way to keep students aware of the railway industry.

This concludes the report of the subcommittee.

CHAIRMAN HUFFMAN: Thank you, Professor Oliver.

As just mentioned, we intend to resubmit to chief engineers a questionnaire asking how many summer positions will be open, and in this way find out how many men will be available. These data will be tabulated and posted at colleges and universities. I think the ratio last year between the jobs available and those wanting jobs was something

like 540 percent in favor of the students. From my own personal experience I received somewhere near 100 applications for 5 jobs. I had quite a choice.

There is one thing we are going to do this year that we didn't do last year—that is to try and get the students to make application in their immediate area. A great percentage of those I received were from the Eastern Coast, and it was rather difficult to interview the applicants in a satisfactory manner. I know that anybody who did have positions open certainly were able to fill them with sophomore and junior students.

Assignment 4—The Role of Engineering Technicians in the Railroad Field.

CHAIRMAN HUFFMAN: Report on Assignment 4 will now be presented by D. W. Tilman, principal assistant engineer, Baltimore & Ohio Railroad. Mr. Tilman.

D. W. TILMAN: Mr. President, members, and friends:

In 1956, Committee 24 made a study of the role of engineering technicians in the railroad field. In a continuation of that study, your committee sent a questionnaire to 94 railroad chief engineers and maintenance officers and to 125 engineering colleges and universities so as to analyze the over-all effect of the engineering technician program and to determine the present and potential use of technicians by the railroads. The questionnaire was answered by 51 percent of the railroads and 71 percent of the schools.

The responses indicate that most of the colleges and universities and most of the railroads agree that the engineering technician program has no adverse effect on the engineering profession or the employment of college graduates.

The railroads report that engineering technicians are used for many types of work in support of graduate engineers. The technician performance has been satisfactory, and their progress meets reasonable expectations.

Most of the railroads are using engineers with less than college degrees and conclude that the employment of engineering technicians presents an opportunity to secure qualified men.

The study has been concluded and this is a final report.

CHAIRMAN HUFFMAN: Thank you, Mr. Tilman. I think this analytical report confirms what most of us believe, that there is a place for engineering technicians within our organization.

Assignment 5—Revise the Brochure "The Railroad Field—A Challenge and Opportunity."

CHAIRMAN HUFFMAN: Our next report, on Assignment 5, will be given by H. E. Kirby, cost engineer system, Chesapeake & Ohio Railway. Mr. Kirby.

H. E. KIRBY: Mr. Chairman, members, and guests:

In accepting this assignment your subcommittee recognized the proportions of its task in attempting to revise the great pioneering job so ably handled by its predecessor five years ago. But time marches on; there are changes in men's thinking; there are technological improvements; the economic law of supply and demand has not been declared unconstitutional.

This work, which necessarily is of some length, contains many points of possible interest to you, but to describe them would exceed our time limit. The book will, we believe, achieve its purpose in effectually presenting the railroad picture if it reaches the hands of those for whom it is intended.

In bringing this work to a conclusion, your subcommittee chairman acknowledges with gratitude the cooperation of his fellow subcommittee members, of the other mem-

bers of Committee 24 and of various specialists in several areas not represented on the committee—including Dr. Thomas Sinclair and some of his colleeagues of the public relations staff of the Association of American Railroads.

And, finally, your chairman wishes to express his distinct sense of gratitude to those members of the Board of Direction who viewed this work understandingly at their meeting last November 7, and voted for its acceptance and publicat'on as recommended. Thank you.

CHAIRMAN HUFFMAN: I am sure the Board Committee on Assignments had the idea when assigning the subject of redeveloping this engineering brochure that there would be a few minor changes made and then it would be submitted to the printer. However, they did not figure on Herman Kirby and his subcommittee. Word for word, picture by picture, page by page, they tore this whole brochure apart and came up with another.

Our executive secretary was a little nonplussed I think, for a while, when we started in on this, but he finally got into the swing of it.

I certainly want to thank the veritable workhorse, Mr. Kirby, and his subcommittee for a fine job well done.

Assignment 7—Stimulate an Interest by College and University Staff Members in Current Railroad Problems, Including AREA Membership.

CHAIRMAN HUFFMAN: The next report will be given by W. W. Hay, University of Illinois, a director of this Association and vice chairman of this committee. Professor Hay.

W. W. HAY: Mr. President, Mr. Chairman, gentlemen:

Subcommittee 7 submits a report of progress.

The subcommittee believes that a first step should be to determine the attitudes of academic staff members. A questionnaire for this purpose has been mailed to all accredited engineering schools of the United States and Canada. The results of this questionnaire will be reported at the next annual meeting.

As one means of interesting both students and staff in railroad problems, a list of varied railroad problems suitable as topics for masters' and doctorate theses are being compiled and will be made available to interested engineering schools, probably within the year.

University staff members thus far contacted have invariably urged expanded railroad participation in sponsored research, including a share of so-called pure or basic research, as a means of keeping railroads within the range of academic interest.

CHAIRMAN HUFFMAN: Thank you, Professor Hay.

As indicated, this study is in the embryo stage, and by this time next year we expect to have a comprehensive report.

Mr. President, this concludes the report of Committee 24.

PRESIDENT MEYERS: Thank you, Mr. Huffman.

Your committee, with 12 professorial members, representing 11 different colleges and universities, provides a splendid contact for our Association with the colleges, and for the colleges with our Association, which I am sure is of mutual benefit. We greatly appreciate the interest which the college representatives on your committee take in the work of the committee, which is clearly reflected in the qual'ty of your reports.

Your committee, and especially Mr. Kirby and his subcommittee, are to be congratulated for the fine job done in revising the second edition of our recruitment brochure, and the Student Recruting Guide will be very helpful.

Your committee is now excused with the thanks of the Association.

Introduction of R. G. May

PRESIDENT MEYERS: We want at this point to interrupt our committee presentations to hear an address by one of our members, with whom most of us are well acquainted because of his appearance on our convention program for a number of years. I refer to R. G. May, vice president, Operations and Maintenance Department, AAR.

In our program as set up in the Convention Issue of the AREA News, inadvertently, it appeared that Mr. May's address was a feature of the presentation of Committee 24, and while I am sure the committee would have been pleased if such were the case, it is a fact that his address is a special feature of our program as a whole, and will be on a subject which cuts across all of our committees, and our membership as a whole.

Since, as I have said, Mr. May is well known to most of us, I am sure he will pardon my making only brief reference to his career. But, for the benefit of any here who may not be informed, I would like to say that he is a civil engineer, and that all of his railroad experience prior to his coming with the AAR as vice president of its Operations and Maintenance Department, on September 1, 1953, was with the New York Central System—he having risen from rodman on that railroad in 1928 to vice president in charge of operations and maintenance in 1952.

Since he came to the AAR in 1953, he has given informed and constructive leadership to its Operations and Maintenance Department, and, in its capacity as the Construction and Maintenance Section of that department, it has been the pleasure and the good fortune of the AREA to work closely with him.

Without further encroachment on his time, I would like to present to you R. G. May, vice president, Operations and Maintenance Department, AAR, who will address us on The Engineer's Responsibility to Railroad Management. Mr. May.

The Engineer's Responsibility to Railroad Management

By R. G. May

Vice President, Operations and Maintenance Department, AAR

Mr. Meyers, members of the American Railway Engineering Association, friends:

It is again my pleasure to appear before the American Railway Engineering Association. You know, there is one advantage to appearing in the middle of the program, or some time well after the start of it, because then we kind of get the run of the thing and maybe have a little bit more to say, but I was quite interested in Mr. Meyers' remarks about the improved economic condition both of the country as a whole and particularly of the railroads. We read a lot about the improved economic situation in our papers and hear many reports by economists on it, but I ran across one the other day that I thought perhaps might be of interest to you gentlemen. I am going to read it to you.

"The Commerce Department reports with some glee that sales and income figures show an easing up of the rate at which business is easing off, which is taken as proof of the government's contention that there is a slowing up of the slowdown." Now please don't try to follow me. [Laughter]

"In order to clarify the cautious terminology of the experts, it should be noted that a slowing up of the slowdown is not as good as the upturn of the downturn, but is a good deal better than either a speedup of the slowdown or a deepening of the downturn, and does suggest that the climates are about right for an adjustment to

readjust. Turning to employment, we find a definite decrease in the rate of increase, which clearly shows that there is a letting up of the let-down. Of course, if the slow-down should speed up, the decrease in the rate of increase of unemeployment would turn an increase into the rate of decrease of employment. [Laughter]

"In other words, a deceleration then would become accelerated, but indicators suggest rather a leveling off followed by a general pick-up, then a faster pick-up, and finally a slowing down of the pick-up."

I think the only thing we can gather from that, gentlemen, is this: The time is about right for a pick-up if you are in a convertible and you are unmarried. [Laughter]

As some of you may recall, last year I directed my remarks to the legislative situation as it affected engineering and maintenance of way departments. This year, I would like to talk to you about what might be called the engineer's responsibility to his industry, his company, his management. But first, a word about the role of the engineer in the railroad way of life.

It is a fact that practically every improvement and technological achievement in railroad history has been the result of research. It is also a fact that nearly every research project connected with maintenance of way and facilities has had its origin in committees of the AREA.

We must, then, out of economic necessity if nothing less, continue to develop improved materials and better methods of doing things. We also must continue our efforts to attract technically trained personnel into the railroad industry.

About this time last year, we were feeling the effects of declining business activity. It took a blow of this kind to jar the public into realizing the need for a healthy railroad industry as a supporting pillar under our national economy. This realization was translated into the Transportation Act of 1958, with which I am sure you are familiar. And I'm sure you are aware that the 1958 Act was no cure all, though it did mark a positive step in the direction of providing much-needed relief along certain lines.

Let us take a minute now to review how the railroads fared in 1958. Carloadings for 1958 were the lowest since the great depression of the '30s. They barely exceeded the 30 million mark, and were the third lowest year of record—exceeding only the aggregates of 1932 and 1933. This comparison, however, is not so dismal as the figure would indicate. Included in the 1958 carloadings total are less-carload loadings, which in 1958 were nearly 7 million under the 1932 level. Carload traffic, on the other hand, showed a gain of nearly 9 million in 1958 over those of the low year 1932.

Ominously, the year 1958 marked the seventh consecutive year of decline in railroad passenger traffic. Passenger miles in 1958 were 10 percent less than in the previous year, and were, in fact, less than in any year since 1939.

Naturally an industry cannot maintain a program of improvements when the traffic and revenues curve takes severe dips while the cost line keeps rising steadily. Railroad spending since World War II for capital equipment and improvements has averaged more than a billion dollars a year. Included in this tremendous program have been such innovations as train and yard radio, closed-circuit television in classification yards, new data-processing equipment, microwave, teletype and other means of immediate communication.

All of these improvements were necessary if we were to remain in the competitive arena with other modes of transportation, most of which have many basic costs paid out of government subsidy. Sharply reduced revenues in recent months, however, have resulted in drastic reductions in railroad spending for improvements of every sort.

Gross capital expenditures for 1958 aggregated $737.8 million, or about half what they were in 1957. This is the smallest reported for any year since 1946. A breakdown of the 1958 total shows that expenditures for road improvements were about a third less than in the previous year, and that outlays for equipment were less than half the 1957 level.

Decreased traffic, however, is not the only malady from which the railroads are suffering. Rising labor and material costs have eaten further into their meager earnings. The seriousness of this problem can be illustrated by the fact that the annual costs of labor and materials have increased by $880 million since November 1956.

Payroll expenses, for example, eat up 52.7 cents of every dollar the railroads receive in revenues. For the sake of comparison, this is more than twice the national average for all manufacturing, and some two-thirds more than in the iron and steel industry.

Featherbedding waste, as AAR President Loomis has already pointed out, gravely aggrevates this situation. And there is more than one kind of make-work practice, too. For example, a very serious form—and one that gets little public attention—is featherbedding by Congressional statute. Each year, the railway labor unions push various make-work bills in Congress under the guise of improving railroad safety. These bills, if enacted into legislation, not only would add to the already unbearable burden of featherbedding costs but also would increase federal regulation of railroads, possibly to the final point of strangulation. I need not point out to you how ruinous either of these would be to the industry and, ultimately, to the nation.

Among the bills the brotherhoods again are asking their congressmen to support are those calling for the operation of motor cars under train-rule conditions, and for bringing Interstate Commerce Commission authority into track, bridge and car inspection and maintenance procedures.

In general, these bills would require the use of more and more employees, and would give the ICC virtual control over many aspects of railroading now left to the discretion of management.

Although such bills are proposed in the name of improving safety, the fact is that the railroads' safety record has shown continuous improvement over the years and is outstanding among all of American industry. The basic objective of these measures in reality is the creation of unnecessary jobs or the protection of existing ones irrespective of operating needs. Such bills constitute a new kind of featherbedding—featherbedding by legislation—and should be recognized by the Congress and the public for what they really are.

The actual effect of such bills would be to tighten the hold of government over our operations and to inflate our costs, thereby impairing our ability to serve the public. Regulation was originally conceived and developed to protect the public interest. Carried too far, however, it becomes destructive and ceases to work for the public good. Featherbedding by legislation would lead to the ultimate in destructive regulation and inevitably, in turn, to government ownership and operation of the railroads.

The impact of featherbedding on both railroad employees and the public welfare is so obviously destructive that it is a wonder labor leaders themselves do not demand its elimination. While borne directly by the railroads, make-work waste is reflected in higher travel fares and freight rates and, consequently, in higher prices generally. And by inflating charges to customers, such waste undercuts our competitive position and contributes to the loss of thousands of railroad jobs—to be precise, more than 500,000 jobs since the end of World War II. What better way to secure jobs and expand employment opportunities than to become more competitive and expand business.

There is no question about how the public itself feels about featherbedding. Mr. Loomis referred yesterday to the number of editorials that had been written in response to his speech. We have seen public reaction expressed in unmistakable terms in scores of editorials in big and small newspapers throughout the country. A recent nationwide public opinion survey revealed that the people oppose featherbedding practices by more than a 2 to 1 vote—in fact, they favor legislation to outlaw such practices. Even among families of union members, the vote is nearly 4 to 3 in favor of curbing featherbedding by new laws.

The impact of featherbedding on the railroads' ability to expand and maintain plant is another doubly serious problem. This is best indicated by the railroads' car ownership and repair situation. The fleet of railroad-owned cars at the beginning of 1959 numbered slightly more than 1.7 million, or some 21,000 fewer than last year. In addition, a drop in repair activities during 1958 resulted in 148,000 cars, or 8.6 per cent of the total fleet, lying idle on repair tracks at the beginning of the year.

This situation has given rise to some apprehension among railroad customers as to our ability to handle an increase in traffic. Although repair and purchase activities have been stepped up in keeping with present business trends, the only lasting solution lies in the railroads' ability to earn more money so they can expand capacity and react adequately to surges in business activity.

Looking to a solution of the need for greater spending for improvements, railroads believe they might best be helped by legislative measures aimed at lightening their tax burden. One such measure, which was eliminated from the Transportation Act of 1958 on a technicality, provides for tax deferral by establishment of construction reserve funds.

Under the reserve plan, a railroad could establish on its books a fund earmarked for capital expenditures. Amounts placed in the fund would be deductible from taxable income by the railroad in computing its corporate income tax. Following use of money in the fund, there would be a corresponding reduction in the railroad's capital depreciation base. Thus, government would recover any initial tax loss through higher future taxes paid by the railroad as a result of lower depreciation deductions. The program, therefore, is one of tax deferral, not tax forgiveness.

The effect of the construction reserve fund program would be, among other things, to level out the peaks and valleys in railroad capital spending. This, in turn, would have a stabilizing effect on the economy as a whole, redounding to the benefit of the shipper as well as the supplier.

The severe capital replacement problem posed by continual inflation in the cost of plant and equipment can probably be solved only by some kind of reinvestment depreciation allowance that would take account of these inflated costs. Thus, if a railroad were to replace a freight car with a new one costing four times as much, the tax laws should allow immediate write-off of the difference between original and current price. Such a reinvestment allowance would stimulate the retirement of old plant and equipment and its replacement with more modern facilities which would provide improved service for railroad patrons.

The railroads also ask to be permitted to recover the money they invest in plant and equipment over a shorter period than present laws allow. In contrast to a present average tax life of 40 years, we ask to reduce the life of railroad depreciable property to a maximum of 15 years in the case of cars and locomotives and to a maximum of 20 years for other property.

Such proposals deserve attention and action by Congress, and we believe the nation

could only benefit from their enactment into law. In reality, the measures we plead for are the bare essentials necessary to help us so improve our plant and services as to attract more traffic, expand revenues and purchases, and create more jobs both on the railroads and among all the supply companies that depend on railroad buying. Here is a goal that is squarely in the public interest. Let's all keep our eyes fixed on it and leave no means untried that may help to achieve it.

In conclusion, a word about your diligent work with universities to attract young engineers into the industry. I have advocated the expansion of these programs for several years. Furthermore, I believe the individual roads should become more active in maintaining contacts with heads of engineering schools for this purpose.

The technician should be active in civic affairs, social clubs and become generally known by and to the public. He has become well rounded professionally. But in this age of rapid technological change, the engineer is also a natural to reach executive positions and he should be prepared in advance to meet management's social and civic responsibilities.

A summary of the engineer's responsibility to management would, under present-day conditions, include many things outside of the scope of his professional duties and responsibilities, so I emphasize these as the more important:

Maintain contacts to keep technically trained personnel coming in the industry.

Provide well-rounded training for new employees.

Be familiar with the individual railroad's problems.

Be familiar with all proposed legislation, state and national, which affects the railroad industry.

Acquaint the public with the railroad story.

I realize this is a big order but if we are to gain recognition and remove some of the shackles which restrain us today we must enlighten the public as to the precarious position of the one mode of transportation which is not only essential to our economy but stands in the first line of national defense.

Thank you. [Applause]

PRESIDENT MEYERS: Thank you, Mr. May. We appreciate your appearing on our program each year because you always bring us something to think about. Certainly one of the featherbedding things that is most important to the engineering and maintenance department is the requirement of full train crews for piloting work equipment. It is one of the things that is forcing us to develop more off-track equipment. Again, Mr. May, I want to thank you for appearing on our program.

Discussion on Water, Oil and Sanitation Services

[For report see pp. 259–288]

PRESIDENT MEYERS: The second committee to report this morning is Committee 13—Water, Oil, and Sanitation Services. I will ask that committee to come to the rostrum now. Please keep in mind the chairman, the vice chairman, and those who are to make reports will come to this table immediately to my left, so we won't lose time.

The chairman of this committee is H. M. Schudlich, engineer of water service, Northern Pacific Railway, St. Paul. Mr. Schudlich, you may proceed with your committee report.

CHAIRMAN H. M. SCHUDLICH: Mr. President, members of the Association, and guests:

Before proceeding with the presentation of our reports, Committee 13 wishes to express its sorrow at the passing of Member Emeritus Edwin Morrell Grime on February 7, 1959. He joined the Association in 1915, was one of our oldest members and was formerly a chairman of this committee. A suitable memoir in his honor has been prepared and it will appear in the Proceedings of this meeting.

MEMOIR

Edwin Morrell Grime

Edwin Morrell Grime, retired engineer of water service, Northern Pacific Railway, passed away February 7, 1959, at the age of 82.

Mr. Grime was born in Minneapolis, Minn., July 1, 1876, the son of John and Emma (Morrell) Grime. He was educated in the Minneapolis public schools and in 1900 received his degree in Civil Engineering from the University of Minnesota.

He spent seven years with the Chicago Great Western Railway in various positions, serving as a division engineer before joining the employ of the Northern Pacific Railway on May 1, 1907.

He served in various capacities, including bridge and building supervisor at Glendive, Mont., and later, at Fargo, N. Dak., until 1925. He then spent six months on a special committee surveying the water resources and the ensuing water requirements for the railway, and was then transferred to St. Paul late in 1925 to become the first engineer of water service. This position he held until he retired on December 31, 1946, after 40 years of faithful service.

He was an ardent and loyal Mason, belonging to Macalester Lodge No. 290, A.F. & A.M.; Minnesota Chapter No. 1 Royal Arch Masons; Damascus Commandery No. 1, Knights Templar and Osman Temple, A.A.O.N.M.S.

He was also a very conscientious worker for St Clement's Episcopal Church and devoted many hours after his retirement to its cause. He was senior warden and a member of the vestry.

The impact of his personality in constructive contribution to the welfare and success of both Masonry and his Church could not be fully realized or evaluated until the time which brought him to the end of his duty.

He was very active in the AREA, which he joined in 1915, serving in various capacities on Committee 13, having been a subcommittee chairman, vice chairman and finally as chairman of the committee. He became a Life Member of the AREA in 1947 and was elected Member Emeritus of Committee 13 on May 22, 1954.

He was also a member of the St. Paul Planning Board, ASCE, AWWA, Engineers' Society of St. Paul, Northwest Maintenance of Way Club, Minnesota Geological Society, Interprofessional Institute and a Registered Professional Engineer in Minnesota.

He is survived by his daughter, Elsie M. Grime of St. Paul, and his sister, Florence L. Grime of Tacoma, Wash.

Mr. Grime will be remember as a gentlemen of sterling character; thorough and conscientious in his dealings, both personal and professional; and the Association expresses its sorrow for the loss of so capable a member.

CHAIRMAN SCHUDLICH: During 1958 Committee 13 held four meetings, one of which was organizational, and at which detailed plans for the year were discussed and clarified.

At the other meetings the various subcommittee chairmen reported their progress and were given suggestions and constructive criticism from the membership for the development of their assignments and which are reflected in the reports.

All of our 11 assignments have been capably handled, and each subcommittee chairman has a report to present. These presentations will only briefly summarize the assignment, but those who are interested in more of the details will find them in the November 1958 Bulletin 546.

I am inviting pertinent comments and questions from the audience after each report has been presented, and the subcommittee chairmen will endeavor to clarify and answer any of your questions.

Assignment 1—Revision of Manual.

CHAIRMAN SCHUDLICH: Our first report is on Assignment 1, which will be presented by the vice chairman of Committee 13, D. C. Teal, superintendent water supply—system, Chesapeake & Ohio Railway.

D. C. TEAL: Mr. President, gentlemen and guests of the Association:

The general rule regarding revision of Manual is that each committee shall critically review the material in its chapter at such intervals as to insure that it be kept up to date. Your committee has this past year reviewed parts 1, 2, and 3 of Chapter 13, with the objective of eliminating those recommended practices that may have been made obsolete by changing times or improved methods. We found in particular that some of the current Manual material on wood water tanks, track pans, and pumps to be no longer applicable. Our specific recommendations regarding revisions of Parts 1, 2, and 3 have been presented to the Association in Bulletin 546.

Unless there is special request for it, I shall omit the reading of this material.

Mr. President, I move that the proposed revisions to Parts 1, 2, and 3 of Chapter 13 of the Manual as shown on pages 260 to 263, incl. of Bulletin 546 and as called to your attention at this meeting, be accepted, and that these changes be incorporated in the manual.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 2—Prevention of Corrosion in Steam and Condensate Lines.

CHAIRMAN SCHUDLICH: The next report will be presented to you by J. J. Dwyer, chief chemist, Chesapeake & Ohio Railway.

J. J. DWYER: The next report is on Assignment 2, entitled "Prevention of Corrosion in Steam and Condensate Lines."

Since this report occupies ten pages in Bulletin 546, it would be impossible for me to present it here, but we would like to give you just a short review of it.

About ten years ago one of our greatest corrosion experts, Dr. H. H. Uhlig of MIT, estimated that corrosion damage in the United States was costing about $6 billion a year. This would now be about $9 billion. Well, our assignment covers just one facet of this corrosion problem, and that is in steam and condensate lines, but the damage in this field alone still amounts to several millions of dollars a year.

So we still consider it quite important, and your committee has been investigating ways and means of alleviating and combatting this tremendous damage and presents its findings in the report referred to.

Up until a few years ago our main defense against this particular type of corrosion damage were certain rules of good mechanical design and good boiler-water treatment which would insure that the steam leaving the boiler would be as free as possible

of steam and carbon dioxide, since these were the two principal "termites" which were eating away our pipes, so to speak.

A few years back substances were developed which would vaporize with the steam and be carried along in the steam lines and condense when the steam condensed. These substances, being of an alkaline nature, would neutralize the carbon dioxide in the condensate, and prevent the corrosion from this particular standpoint.

The first such substance to be used, of course, was ammonia, but ammonia is deadly corrosive to copper and zinc and some other metals, and soon fell into disuse. A few years ago certain materials which are now known as neutralizing amines were developed which were not aggressive like ammonia, and which, therefore, have come into popular use and have gone a long ways toward preventing corrosion from the carbonic acid. However, the neutralizing amines have just one drawback. They do not protect against oxygen. That is where the third part of our report comes in, which describes the filming amines—a relatively new advancement in this field. The filming amines protect against corrosion by an entirely different principle. Rather than neutralizing the acid and having to be used in amounts proportionate to the amounts of acid in the line, the filming amines form a film—a non-wettable film—on the inside of the pipe, and only very small dosages of from one to three parts per million are required to do this job. It doesn't make any difference then whether the condensate contains carbon dioxide, oxygen, or both. The filming amine still does the job. These filming amine molecules are of a long slender type which attach themselves to the metal at one end, and sort of stand on end and pack closer and closer together like a bunch of toy soldiers standing in close order drill until finally there just isn't any room left to permit the molecules of carbon dioxide, water, or oxygen, to get through to touch the metal. If there isn't any contact, there isn't any corrosion.

This is a final report, presented as information, with the recommendation that it be submitted in condensed form as Manual material next year.

I am told that we have time for possibly one question. Would anyone like to ask it?

R. G. Angell [A. M. Byers Company]: Mr. Dwyer, I have read your very excellent report on the subject. I am wondering if it wouldn't be of interest to the Association to comment on your recommendations in regard to weight of pipe. I think there has been a change since your report was published.

Mr. Dwyer: Mr. Angell, I am happy to answer your question, particularly since there has been a change in the pipe weight recommendations since the initial publication of the report in Bulletin 546 last November. The "good mechanical design" criteria discussed in the first section of the report indicated that the heavier the pipe, the longer it would last. On this basis, double extra strong pipe was recommended. However, subcommittee investigations have continued since the first publication of the report, with considerable credit being due to D. C. Teal for actual field service performance records established by the filming amines. It is now indicated that, to a considerable extent, we may have our cake and eat it, too. By this I mean that the efficiency of the filming amines has been established so that it is no longer necessary to use the heaviest weight pipe, which opens the way for great savings for the industry by permitting the use of more economical weights of pipe. The revised recommendation of your committee specifies that "extra strong wall pipe and fittings (ASTM Schedule 80 or heavier) should be used in condensate return lines."

President Meyers: Thank you, Mr. Dwyer.

Mr. Dwyer: I would like to introduce J. C. Roberts, fire and sanitary engineer,

Union Pacific Railroad who is substituting for the chairman of Subcommittee 3, J. M. Bates, assistant to chief engineer, Union Pacific.

Assignment 3—Design, Construction, and Operation of Coach-Servicing Facilities to Comply with Regulations of U. S. Public Health Service, Collaborating with Joint Committee on Railway Sanitation, AAR.

J. C. ROBERTS: Mr. President, Mr. Schudlich, ladies, and gentlemen:

Last fall at its regular September meeting Committee 13 approved a proposal to submit a request to the Board of Direction of the AREA for a research project on coach-water hydrants and established five objectives, which were published in Bulletin 546. Early this year the committee membership was requested to submit plans, photographs and other information on the coach-water hydrants in service on their railroads. As a result of the studies of these plans, Subcommittee 3 is recommending an appropriation of $15,500 for research to be conducted at the AAR Research Center and to be divided as follows:

Salaries for research personnel, including any sums paid for consulting services, $8,500.

Travel expenses, $1,500.

Materials, including special designs, etc., $3,000.

Equipment, including specialties such as jigs, dies, and other tools, $2,000.

Miscellaneous, including stationery, postage, etc., $500.

We feel that such a project is justified for these six reasons:

1. There is no standard design of coach-water hydrants on the American railroads, nor has any attempt at standardization ever been made, to my knowledge.

2. Plans submitted to Subcommittee 3, Committee 13, bear approval dates back to 1928. Installations covered by these and other plans of more recent date will not satisfy present minimum requirements of public health authorities. Construction of coach-watering facilities to replace existing out-dated installations would, in most instances, involve relatively large initial expenditures and high maintenance and operating costs.

3. No individual railroad, or group thereof, is prepared to undertake a research study of this scope on its own initiative.

4. There are no commercially manufactured coach-water hydrants on the market which will meet the five objectives of Subcommittee 3's assignment.

5. Successful design and development of a coach-water hydrant satisfying the objectives of the Subcommittee 3 assignment would make it possible, in many instances, to replace existing facilities at nominal cost and realize significant savings in operating and maintenance expense thereafter.

6. Many hydrant installations in service on the railroads today are known to be inadequate in design and insanitary in their operation. It is paradoxical that the most expensive hydrants to maintain and operate are probably the most insanitary.

Do we have time for some questions? If there are any questions from the floor, I think we have a few minutes.

PRESIDENT MEYERS: There doesn't seem to be any questions, Mr. Roberts. I am afraid we are running behind. Does that conclude your report, sir?

MR. ROBERTS: Yes, this concludes the report of Subcommittee 3, and I would like to introduce now W. F. Arksey, engineer water service and fuel facilities, Great Northern Railway, who will present the Subcommittee 4 report.

Assignment 4—Cathodic Protection of Pipe Lines and Steel Storage Tanks, Collaborating with Electrical Section, AAR.

W. F. Arksey: Mr. President, members, and guests:

Our report this year is the third part of a four-part study and is offered as information. In it we cover the principles involved in the selection of instruments for conducting preliminary surveys and for checking installations after cathodic protection has been applied.

The report also gives a bibliography of publications on the subject of cathodic protection which may be useful to those wishing more detailed information.

Are there any specific questions on our report as presented? If not, the next report is on Assignment 5, and I would like to introduce Subcommittee Chairman E. M. Walters, assistant engineer water service, Northern Pacific Railway.

Assignment 5—Transportation of Solids by Pipelines, Collaborating with the Pipeline Division, ASCE and Other Interested Organizations.

E. M. Walters: Mr. President, Mr. Chairman, and gentlemen:

Two companies in the United States and one in Canada are transporting solids by pipeline over long distances at the present time.

The American Gilsonite Company at Grand Junction, Colo., operates a 72-mile pipeline to transport Gilsonite from the mine to the refinery. Eight-mesh material is pumped through a 6-in line as a 40-percent slurry at the rate of 700 tons per day. The line cost $2 million to construct, and operating costs are $1 per ton. This line eliminates a 180-mile truck haul.

Pittsburgh Consolidated Coal Company delivers 3600 tons of 14-mesh coal per day through a 10-in pipeline 110 miles long to the Cleveland Electric Illuminating Company. The cost is 40 percent that of rail transportation.

International Nickel in Canada has a 7½-mile pipeline for transportation of ore and tailings. It uses 8 to 13-in wire-bound, creosoted wood stave pipelines. This process has been used since 1951.

Several foreign lines are said to be in the planning stage.

Subcommittee 11, Committee 16, has prepared a report on the economics of pipeline transportation.

Transportation of solids by pipeline appears to be a promising project and should attract considerable interest.

I would now like to introduce the chairman of Subcommittee 6, T. A. Tennyson, engineer tests and sanitation, St. Louis Southwestern Railway.

Assignment 6—Railway Waste Disposal, Collaborating with Joint Committee on Railway Sanitation, AAR.

T. A. Tennyson: This year your committee accumulated information on waste disposal by dividing the subcommittee into task groups, each with its own phase of the over-all project, and our report summarizes the progress of this study.

Disposal of waste water containing oil, which is the major problem in railway waste disposal, can be solved by reducing the waste of this material, handling oil-laden wastes from cleaning operations separately from general shop storm water, and application of primary separation with chemical treatment and final cleanup methods when emulsions become a problem. A thorough knowledge of the regulations set up by state and federal authorities and the chemistry and physics of the processes involved is essential.

Final disposition of the waste oil which has been removed by separation requires

careful study and analysis of local conditions. Disposal of solids removed from waste separation plants along with general trash and rubbish must be carefully planned to avoid further trouble and costly handling. The use of enclosed containers, which can be easily handled by fork-lift trucks, trailers, etc., as temporary storage facilities has been worked out quite thoroughly by a number of firms which are in a position to offer systems that can often save considerable sums in labor costs.

This report of progress is presented as information.

I would like to now introduce A. W. Johnson, steam heat and water service engineer, Santa Fe, who is chairman of Subcommittee 7.

Assignment 7—Inspection and Maintenance of Diesel Fuel Oil Storage Tanks.

A. W. JOHNSON: Your committee recommends the procedure for maintaining diesel fuel oil storage tanks and to insure good-quality fuel oil published in Bulletin 546, pages 278–279.

This involves maintenance of the physical tank structure, periodic testing of diesel fuel oil quality and recirculation to avoid oxidation or enlargement of particle size which cause filter stoppage or locomotive fuel injector trouble, and finally, maintenance practices to protect against fire.

This is a progress report to be completed this year.

If there are no questions, I will call on V. C. Barth, chief metallurgist and engineer of tests, Chicago & North Western Railway, who will report on Assignment 8.

Assignment 8—Methods of Controlling Spillage of Fuel Oil at Diesel Fueling and Unloading Stations.

V. C. BARTH: Mr. President, Mr. Chairman:

This report covers methods of controlling spillage of fuel oil at diesel fueling and unloading stations and as such is only a progress report.

To control spillage when unloading fuel oil, it is the general practice to empty tank cars either by overhead or bottom facilities. Spillage losses due to bottom unloading is practically nil, while overhead unloading results in a loss of about 25 gal. which principally represents the amount of fuel remaining in the bottom of the tank cars. This loss, by some, is regarded desirable as it represents the sludge accumulated.

With respect to automatic fueling facilities, it is generally agreed that the devices now available are in the stage of development. Several have been used quite extensively, but none are actually acceptable because success of such equipment is largely dependent upon standardization and interchangeability.

It is the committee's request that the manufacturers get together in an effort to solve this problem.

Up to the present time it was impossible for your committee to establish the true economics of unloading and fueling devices but expects to accomplish this end during the next year. Thank you.

I now wish to introduce the chairman of Subcommittee 9, R. S. Glynn, director, Sanitation Research and Development, AAR.

Assignment 9—Disinfectants, Deodorants, Fumigants, and Cleaning Materials, Collaborating with Joint Committee on Railway Sanitation, AAR.

R. S. GLYNN: The subjects studied under Assignment 9 are disinfectants, deodorants, fumigants, and cleaning materials.

The data on cleaners were reported a year ago. During the past year the fumigants and disinfectants received attention.

In fumigation, methyl bromide has become known as the "fumigant of choice" in less than 25 years. Its advantages and the precautions to be taken in its use are discussed. Several fumigants for special applications are also discussed. The report on fumigants is offered as information.

A preliminary report on disinfectants was made during the past year in which were discussed some of the general principles of disinfectants, including a glossary of terms to be used in the final report to be made this year.

If there are no questions, the next report will be presented to you by C. F. Muelder, assistant to engineer of buildings, Chicago, Burlington & Quincy Railroad, who will report on Assignment 10 for R. A. Bardwell, nuclear engineer, Denver & Rio Grande Western Railroad, chairman of the subcommittee.

Assignment 10—Railroad Aspects of Radioactive Substances, Collaborating with Joint Committee on Railway Sanitation, AAR.

C. F. Muelder: Mr. President, Mr. Chairman, members, and guests:

I am reading this report for Robin Bardwell who is chairman of this assignment. Robin is a handsome young man who has been drafted to conduct the ladies on their tour this morning.

During the past year, several railroads in the United States have used radioactive piston rings to measure the rate of piston ring wear in diesel locomotives. These tests have proved to be extremely fruitful. They have been used to measure the effects of various fuel oils, lube oils, and engine components on piston ring wear.

The hazards involved in performing these tests have been very small. It has been the experience of the railroads using the radioactive measuring technique that no person has been exposed to as much as one third of the allowable radiation tolerance dose. This can be stated in another way by saying that during the several months that these tests have been run, the most radiation received by any one person has been less than the amount of radiation received from one chest x-ray.

The disposal of waste products associated with these tests has been no problem. The lube oil from the test engine has very little radioactive material in it. In fact, after a brief storage period, the activity of this lube oil is below the allowable limit for drinking water. The radioactive piston rings which are eventually removed from the engine are disposed of by sending them to a licensed radioactive disposal firm.

At this time I would like to introduce C. E. De Geer, assistant engineer water service and fuel facilities, Great Northern Railway, who will report on Assignment 11.

Assignment 11—Methods of Heating Fuel Oil to Permit Winter-Time Use of High-Pour-Point "Economy" Grade Fuel Oil.

C. E. De Geer: Mr. President: Our report this year covers the reasons for heating diesel fuel oil, how to determine the amount of heat to maintain the desired temperature level and to bring added cold oil up to this level in a specified time interval, and the costs of heating fuel oil.

It also discusses the data found in a 25,000-gal heated, above-ground, insulated storage tank at Crookston, Minn., that has been equipped with various testing and recording devices. As the mean temperature at this location during the months of December, January, and February has been about 12 deg below zero, the tests have been quite conclusive.

If there are no comments, I would like to turn the balance of our report back to our chairman, Mr. Schudlich.

President Meyers: Thank you, Mr. De Geer.

CHAIRMAN SCHUDLICH: Are there any other questions on any of the reports?

If not, we will proceed with the special feature.

It now gives me a great deal of pleasure to present E. H. Myers, engineering editor, Modern Railroads. Mr. Myers is a member of this committee and has a good background in railroad engineering. He is very much interested in the facets of transition in modern railroading. Mr. Myers will now speak on, "The Broadening Field for Railway Water Service Engineers."

The Broadening Field for Railroad Water Service Engineers

By Edward T. Myers
Engineering Editor, Modern Railroads

MR. PRESIDENT: Mr. Chairman, members and guests:

It is a pleasure to be here today to talk to you people. When Mr. Schudlich invited me to speak, I thought that some of you engineers would probably have topics of greater interest than anything I could bring before you. However, he felt that I had a crystal ball hidden away in the office. I guess editors are supposed to have crystal balls so they can look into the future, so I went back to the office and looked into my crystal ball. Well, I guess I must have looked into the same ball that Dan Loomis looked into because this subject of the challenge of change and progress in railroading came to my attention.

1. The Shifting Scene

I regret to say that many persons in the railroad industry look upon the water service engineer as an anachronism—a leftover from the age of steam. Unfortunately, these people completely overlook the growing place that testing—chemical testing in this instance—holds in industry and especially in the railroad industry today. Perhaps the very name "water service" suggests a limited field of endeavor—this is far from the truth.

As I gaze into my crystal ball, I see a very different picture. I see the amazing adaptability of the water service engineer in the face of drastic change. His area of work, like the railroad business itself, has undergone a revolution since dieselization. Today, even water must meet new standards of purity as it flows to diesel cooling systems and automatic boilers.

Like the railroad industry itself, the water service engineer possesses vitality and skill and can quickly adapt himself to changing conditions and new duties. His knowledge of chemistry, testing techniques, and utilities, to name only a few areas, enables him to meet the requirements of the atomic age. His skills will prove ever more valuable to an ever-changing industry.

But who is a water service engineer? What kind of men form AREA Committee 13—Water, Oil, and Sanitation Services? Some members are chemists, utilities men, water supply engineers, engineers of tests, sanitation engineers, nuclear engineers, metallurgists, and diesel fuel inspectors. This group of specialists and their work touch all departments . . . deal in some manner with all phases of railroading.

Thus, you can see that Committee 13 represents a talent pool of experienced men whose many skills are available to the railroad industry. Managements of all railroads, not only those with extensive test departments but all, have the opportunity of drawing upon the collective knowledge of these committee members. These men are capable of

pointing the way to substantial economies by reviewing past operations and obsolete practices . . . recommending new, efficient procedures and techniques.

The shift from steam to diesel power lightened the task of the water service engineer only momentarily. The shift was largely one from quantity to quality. Diesel cooling systems and automatic steam generators demand higher standards of water purity. Precise laboratory control of water is the word. Rust inhibitors necessary for the protection of the system create problems of disposal and toxicity.

Duties of the water service engineer in his original field are, thus, more critical than ever. A trend from the large coal-fired boiler in a central boiler plant to automatic boilers spotted where needed is continuing. The modern automatic boiler is a highly scientific piece of machinery operating at a high level of efficiency. The importance of proper feed water to equipment of this type can not be overestimated if full satisfaction and efficiency is to be obtained.

Similarly, automatic steam generators used on diesel locomotives and in various applications, such as car cleaning, require properly treated water and proper treatment of the boiler coils.

Recently, demands of management for more economical diesel fuels in the face of rising costs for light, straight-run distillates conflict, in some cases, with the desires of the operating and the mechanical departments. This is no static situation, but rather one in which almost daily changes can be expected. Competition from other fields constantly threatens the supply of the high-grade fuels and drives up their prices. Advent of the economy fuels is presenting the water service engineer with storage problems. Some of these fuels are unstable in storage; some have increased sulfur content which, it is believed, increases corrosion of tanks and distribution pipes.

Attempts to improve these fuels include treatment with atomic radiation. Experiments on the D&RGW include the addition of irradiated coal to diesel fuel. Propane and atomic fuels are being studied, elsewhere, for possible use. Each of these experiments will create new problems in testing, storing, and handling.

Growing Complexity of the Field

As an example of the growing complexity of the water service field, consider the prevention of corrosion in steam and condensate lines. To cope with this problem, a nice understanding of chemistry is essential. Not merely is feed-water treatment involved, but steam itself must be treated to neutralize corrosion forming substances. These treatment chemicals belong to the amine family and have, at least to me, very formidable names. It's obvious I'm not a chemist or I'd roll off a few.

In employing the corrosion resisting chemicals, the water service engineer faces another problem: for what is the steam used? If it involves food processing, then he must guard against the application of toxic compounds.

But corrosion is not confined to the inside of pipelines, boilers, and tanks. Metal, whether exposed to air, water, or soil, is subject to corrosion. While proper paint or finishes, or wrappings will give extended protection against atmospheric corrosion, the problem in buried metal is more severe. Here the water engineer calls upon his knowledge of chemistry and physics to produce electric or cathodic protection. To detect the need and to determine the requirement for protecting a given structure, the engineer must make a survey of the electrical potentials and currents associated with the structure.

As a result of the water srevice engineer's efforts to stop or at least retard corrosion, life of structures is extended, and many millions of dollars are saved annually for management.

How does the modern water service engineer help the rest of you engineers? How does he help the industry? He helps in the compounding and checking of weed killers . . . in the checking of creosote . . . in testing paints and finishes . . . in corrosion prevention work . . . and in many other ways.

As you well know, an increased demand for the testing of products used by the railroads has arisen. The aim is to insure economical purchasing plus the maintenance of quality and uniformity.

As the number and the complexity of products increase, the role of the chemist and the test department increases. The ever-changing variety of cleaners available must be investigated. Thousands of new products must be checked or rechecked each year. These analyses are an important aid to engineering, mechanical, and stores departments. They aid in setting up specifications and controls to guide the purchasing department.

2. Important Duties of the Water Service Engineer

As I've pointed out, the duties of the railroad water service engineer have greatly broadened in the past decade. They're broadened to keep pace with the changing conditions of our industry. As might be expected, the area covered by this man is not clear cut. His work varies from railroad to railroad. It involves many materials and processes. It ranges across the fields of chemistry, mechanical engineering, health and biology, atomic physics, transportation, plumbing, utilities, and many others. Almost daily its scope broadens as scientific techniques are applied to an ever-broadening field. Many railroads are finding it well worthwhile for them to broaden the budgets allotted to the water engineer . . . to improve the facilities of the chemical laboratory . . . to add new test instruments . . . to extend the test department.

While I've mentioned the additional problems created by economy fuels, lubricating oils are also of critical importance. Routine tests on these determine that specifications are being met by the refineries.

Another way in which the water service engineer saves railroad management substantial sums lies in the watchful eye of the water service engineer who checks on diesel fuel tanks. Here a valuable inventory may become contaminated through ground sources of water or may actually leak away. The water engineers, acting through Committee 13, continue to exchange information and study the means of reducing the loss of oil at diesel fueling and unloading stations. Not only is this an economic waste, but also it creates a disposal problem and a fire hazard.

With heavier grades of oil and high-pour-point economy fuels being stored in out-of-door tanks, means of heating this oil must be devised for northern climates. A current project of Committee 13 involves just this.

At times it seems that the water service engineer, like the small town doctor of yore, must be an all-around specialist. Problems of the bacteriologist face him as he choses from a variety of products and chemicals to meet specific needs in disinfecting, deodorizing, fumigating, and cleaning.

One field which requires increasing attention is that of sanitation. It is up to water service engineers to keep informed on the status of all railroad facilities and operations that come under the interstate quarantine regulations and the various state river pollution laws. These engineers accompany the state health people on their inspection tours and take whatever action is necessary for the correction of sanitary defects, including plans and estimates for required improvements.

Disposal of noxious wastes (produced by chemicals used in the shops) will be

more difficult as communities grow in size, surrounding once-isolated railroad facilities. Accordingly, stiffer regulations against stream pollution can be expected.

Today, the chief offender appears to be emulsified oil, perhaps mixed with chemicals from a cleaning vat. To cope with this, the water service engineer falls back upon his knowledge of gravity type oil traps, settling basins, use of flocculating agents and chemicals, filtration techniques, and absorption techniques.

The Water Service committee constantly comes up with money-saving ideas as ways to utilize this waste oil. Where feasible, the committee suggests its use as boiler fuel, or if this cannot be done, its use as a weed killer.

3. New Fields in the Atomic Age

On the horizon, as you well know, is a variety of applications for atomic and various nuclear products—both in industry and on the railroad. The extensive use of such materials will create problems for the water service engineer. In addition to routine problems of disposal of radioactive wastes, the water service engineer will have to cope with unexpected accidents on the road or in the shop when radioactive materials are accidentally released, contaminating an area. And we should not overlook the possibility of radioactive contamination as the result of atomic bombings. Under such conditions, it would be essential to decontaminate areas of railroad operations as quickly as possible. Again management and operating men will look to water service engineers to cope with such problems and to come forth quickly with a plan of action.

Other radioactive problems which may soon confront the committee range from the weighing of freight cars by atomic radiation to the use of atomic fuel in boilers and turbines. Here the water engineer so long concerned with water as a boiler fluid may find himself confronted with other substances—liquid or gaseous—feeding the atomic turbine of the future.

The new science of nuclear physics has created an entirely new tool for the study of such old problems as rates of wear, rates of corrosion, and the causes of hotboxes. Measurements of minute quantities of radioactive wear materials can be made with great accuracy, and the amount of material involved and rate of wear can be calculated accurately. Thus, in hours or days, results can be obtained that took months or years with former techniques.

Using this technique, the D&RGW has carried out a remarkable study on the granular interpenetration of overheated journals. Similarly, tracer techniques can be used to study the effects of sulfur content in diesel fuels.

Many other applications of atomic techniques are not only possible, but also have been tried by railroads such as the NYC and the D&RGW. Ray McBrian, director of research of the latter road, has reported on the progress abroad in atomic locomotives. He has pointed out how radiation can be used to detect rotten ties and hidden rail faults; how irradiation can be used to harden soft wood intended for ties.

For some years now, Cobalt 60, a radioactive material, has enabled railroad test departments to look inside of metal castings. Subsurface flaws in metal parts can be detected readily.

Undoubtedly these techniques are in their infancy and will be applied in many ways to extend our knowledge of the unknown. Experience of many railroads shows that radioactive techniques are valuable and can be utilized at little or no hazard to personnel.

To better move ahead with atomic developments, keeping all AREA members informed, Committee 13 has formed Subcommitteee 10, "Railroad Aspects of Radioactive Substances," with R. O. Bardwell, D&RGW, as chairman.

The Field Ahead

Many exciting developments lie in the days immediately ahead. Would the water service engineer of 25 years ago expect to be involved in a new method of transportation? Probably no more so than you would expect to be dealing with heavy water.

But as you know, Subcommittee 5 of Committee 13 is already in action studying the transportation of solids in water pipes. This is being done in collaboration with the Pipeline Division, ASCE, and other interested organizations. As your committee has recommended, the railroads should maintain an interest in the development of these pipelines so that they can take advantage of their economic aspects. Sulfur, coal, gilsonite (uintatite, asphalt), ores, and similar granular material are either now moving by pipeline or can be moved in that manner.

In connection with such projects, the water service engineer must be concerned with pumps, internal and external corrosion, abrasion and erosion of the pipe, water pressures, and de-watering at the end of the pipeline. In the future, the subcommittee will report on these points.

New assignments undertaken by subcommittees of Committee 13 include "Plastic pipe and its uses on railroads" and "Prevention of corrosion in hot and cold water systems."

Applied research, more often than theoretical research, is a role to which the water service engineer has become accustomed. Here lies a big future for railroad progress.

4. Utilizing the Talent Reservoir of Your Water Service Engineer

Doubtlessly in the preparation of this talk, I've overlooked many of the present and future activities of the water service engineer. I'll blame that on my crystal ball. I hope, however, that I have indicated the importance of these men and of their committee (Committee 13) to our industry and pointed out some of the areas in which their special talents can aid their managements in the days ahead.

Whether these days are good or bad, much is expected of the water service engineer, and you may feel certain that he is standing ready to meet the new and special requirements which technological change is producing. [Applause]

CHAIRMAN SCHUDLICH: Thank you, Ed, for the informative, inspiring, and illuminating address.

Mr. President, this concludes the report of Committee 13. I wish to thank all the subcommittee chairmen and the committee members for their active and enthusiastic interest and cooperation during the past year, and last but not least, I want especially to thank Neal Howard, for his wonderful advice and assistance.

I would now like to present Don C. Teal, superintendent of water supply—system, Chesapeake & Ohio Railway, who will be the new chairman of Committee 13, [Applause] and E. C. Harris, engineer of tests, Missouri Pacific Railroad, who will be vice chairman of the committee in 1959. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Schudlich. I want to congratulate your committee on having reports on all 11 of your assignments. It is evident from both the number and character of your reports, and the comments of Mr. Myers, that there is still a large field of activity for your committee and for water service engineers in its personnel.

We welcome Mr. Teal and Mr. Harris as the new chairman and vice chairman. I also want to thank Mr. Myers for the special paper.

The committee is excused now with the thanks of the Association.

Discussion on Wood Bridges and Trestles

[For report see pp. 555–563]

[President Meyers presiding.]

PRESIDENT MEYERS: Since we are running behind time, I would like to have Committee 7—Wood Bridges and Trestles, come immediately to the front table. The chairman of this committee is F. E. Schneider, assistant engineer, Bridge Department, Santa Fe, Chicago.

Mr. Schneider, you may proceed with your report.

CHAIRMAN F. E. SCHNEIDER: Mr. President, members of the Association, and guests:

Since I have been appointed chairman, we have also had to appoint a new vice chairman. At this time I would like to introduce the new vice chairman of Committee 7, Kenneth De Blois, assistant engineer of bridges of the New York Central Railroad. Will you please arise? [Applause]

The report of Committee 7 will be found in Bulletin 548, beginning on page 555. We are reporting on three of our ten assignments this year. The reports on Assignments 1 and 6 are submitted for adoption and publication in the Manual, while the one on Assignment 2 is submitted as information with the recommendation that the material be published in the Manual a year hence. The committee invites your comments and questions at the conclusion of each presentation.

I will introduce the topic and speaker of our special feature after we have presented our committee reports.

Assignment 1—Revision of Manual.

CHAIRMAN SCHNEIDER: Our first report is on Assignment 1 and will be presented by the former subcommittee chairman, Milton Jarrell, assistant engineer of bridges and buildings, Baltimore & Ohio Railroad. Mr. Jarrell.

MILTON JARRELL: Mr. President, gentlemen:

Last year your committee presented as information general notes and plans for open-deck pile and framed trestles, multiple-story trestles, and ballasted-deck pile and framed trestles. The report was published in the 1958 Proceedings, Volume 59.

As the result of further review by the committee and some suggestions by other members of the Association, minor revisions have been made in several of the plans. These revisions are described in report on Assignment 1 in Bulletin 548, January 1959.

Your committee recommends, and I make a motion, that these general notes and plans (Figs. 1 to 16, incl.), as revised, be adopted and published in the Manual to replace obsolete drawings, Figs. 1 to 8, incl., presently appearing in the Manual.

(Note: In connection with the adoption of new Figs. 1 to 16, incl., Figs. 9 and 10 covering timber pile piers presently appearing in the Manual should be renumbered as Figs. 17 and 18, respectively).

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 2—Grading Rules and Classification of Lumber for Railway Uses: Specifications for Structural Timber, Collaborating with Other Organizations Interested.

CHAIRMAN SCHNEIDER: The second report is on Assignment 2. Since our subcommittee chairman, R. E. Kuehner, structural designer, Nickel Plate, could not with us this morning, I have asked Bill Howe, engineer of bridges and buildings, Bessemer & Lake Erie Railroad, to present the report.

W. C. HOWE: Your committee submits as information the table on "Classification

of Stress-Graded Lumber for Railway Uses" shown in Bulletin 548. The tables classifies stress-graded lumber as to minimum quality recommended for railroad use for various structures. The table is an end-use guide and was prepared to aid designers and requisition writers in reaching decisions as to stress grades of lumber. The grade listings for these end uses are purely advisory and are not to be construed as mandatory for requisitioning purposes where higher grades are deemed necessary for a given use at an installation. The grades listed for southern pine, fir and hemlock have been reviewed and approved by the proper lumber association.

This is the first table of this type that Committee 7 has prepared, and it is presented to the members of the Association for perusal and resultant comments or criticism.

Next year, it is proposed to submit the table with the recommendation that it be adopted and published in Part 1, Chapter 7, of the Manual.

Assignment 6—Design of Timber-Concrete Composite Decks, Collaborating with Committee 8.

CHAIRMAN SCHNEIDER: The third and last report will be given by Professor Oliver from the University of Illinois. Professor Oliver.

W. A. OLIVER: Mr. President, members, and guests:

Last year your committee presented as information a drawing showing recommended design practice for timber-concrete composite decks for highway loading. Your committee now recommends that this drawing be adopted for publication in the Manual as Fig. 2 under Recommended Practice for Overhead Highway Bridges, and I so move.

[The motion was duly seconded, was put to a vote, and carried.]

PROFESSOR OLIVER: As I did a year ago I would, also, like to call to the attention of interested persons two reports which have previously been presented as information by this subcommittee. A paper by T. K. May of the West Coast Lumberman's Association entitled "Composite Timber-Concrete Construction" will be found in the Proceedings, Vol. 56, 1955, page 642. This paper covers the development and use of this form of construction. Two years ago we published as our report a paper entitled "Design of Timber–Concrete Composite Decks" which can be found in the Proceedings, Vol. 58, 1957, page 678. This paper discusses the assumptions and approximations made in the standard design procedures.

Mr. President, this completes the report of the subcommittee.

PRESIDENT MEYERS: Thank you, Mr. Oliver.

CHAIRMAN SCHNEIDER: Our special feature will now be presented by Mr. F. P. Drew, assistant research engineer structures of the AAR research staff. Some old bridge stringers in track and in the AAR laboratory have been tested under Mr. Drew's direction; thus I consider Mr. Drew especially qualified on the subject, "How Serviceable Are 50-Year-Old Bridge Stringers?"

It gives me a great deal of pleasure to at this time present to you, Mr. Drew.

How Serviceable Are 50-Year-Old Bridge Stringers?

By F. P. Drew
Assistant Research Engineer Structures, AAR

President Meyers, members and guests:

From the subject of this presentation, you may be led to believe that I am going to give you some definite rules by which you can determine the remaining service life of old timber stringers. Let me assure you that I can only give you some criteria or yardsticks which may be useful, along with your own inspections, to enable you to judge the probable remaining useful service life of old stringers as related to your own particular requirements.

The fact that there are approximately 1800 miles of timber bridges on the American railroads—equal to that of steel and twice that of concrete—is evidence that the railroads have found timber to be a particularly useful material. One large Middle Western railroad alone reports that it has 140 miles of timber trestles and that of this mileage 40 percent are over 45 years old and 16 percent are over 50 years old. The reason such a large percentage are about the same age is that these trestles were built in the early 1900's when the railroad was constructing many miles of new trackage. This is probably typical of other railroads, too. If age alone were to be the criterion for trestle renewal on the railroad just mentioned and if all its 50-year-old stringers were to be replaced this year, about 2000 panels of trestle would be required! Obviously all of these cannot be replaced in one year, and a decision must be made as to which ones can be safely carried over a few more years. It seems apparent, therefore, that the serviceability of these old stringers becomes a very real and important issue.

The bridge engineer's decision on stringer renewal is usually based on inspection reports from the field. However, inspection of a stringer in the field will often only indicate certain physical characteristics which may have an influence on the strength of the stringer. For instance, decay can be detected with a probe or increment borings, but is the evidence of minor decay in the end of a stringer justification for its removal? Such a condition may result in local crushing, and this can be corrected with shims. How much decay can be tolerated? Checks can be detected by a visual inspection and their depth can be approximated, but is such information adequate to justify removal of the stringer? Checks can be readily detected in the outside stringers, but what about those inside stringers where only the bottom surface is exposed? These strength-reducing factors are important in the inspector's report, but are only relative with respect to over-all serviceability of the stringer.

The degree of serviceability must also include the location of the stringer in the deck and the magnitude of the stresses under service loads. In the current program of tests of timber trestles conducted by the AAR, it has been found that the maximum stress at the center of span under diesel locomotives rating between E40 and E49 does not usually exceed about 800 psi. However, the stress varies considerably across the deck, and those stringers near the outside carry much less load than those under center of track.

Thus, there are many factors which should be considered before removing a stringer from a bridge, but how often have you asked yourself when the stringer has been taken out: could it have safely carried load for a few more years? It is the answer to this question that the AAR, upon the recommendation of Committee 7, is seeking in its program of testing old bridge stringers.

Full-size stringers which have been removed from service are being used in this

investigation. The load is applied in the laboratory to closely duplicate that which the stringer was subjected to in the bridge. The load is applied by a repeated load machine in a controlled atmosphere to maintain the moisture content of the wood. After the stringer has carried 1,000,000 cycles of its service load, the load is increased and cycling continued for another 500,000 cycles. Stringers from the same bridge are tested statically to determine their ultimate static strength. It has been observed in field tests that equally high stresses occur occasionally under cars as under the locomotives. Hence the use of 1,000,000 cycles of stress in the laboratory indicates that if these high stresses were produced in the stringer six times during the passage of a train, that 25 trains a day could cross the stringer for nearly 20 years. Thus, these 1,000,000 cycles could be interpreted as an extended service life of 20 years.

This laboratory program has been underway only a short time, but already the results are significant.

The stringers in the first series of tests were 50 years old and untreated, and from all outward appearances the bridge engineer was certainly justified in removing them from service. There was some checking, but the most serious defect was extensive decay in the ends which reduced the available timber for end bearing. Otherwise the timber appeared sound.

During the first few applications of the service load, the soft, decayed end bearing crushed about 3/8 in, and during the next 500,000 cycles an additional 3/8 in of crushing was observed, but the rate of crushing reduced as the load cycles increased. The bending stress was 800 psi, and it appeared that the stringer could have sustained many more cycles of this service load. Under a load of 1½ times the service load one of the stringers carried 300,000 applications of load before failure from loss of part of the bearing area. Loaded statically, one of these stringers carried nearly five times its service load and over twice its design load. Failure occurred in bending, but the crushing at one end was a contributing factor. The load was reapplied after failure and the stringer carried nearly four times its service load. Both the static and repeated load tests of these stringers indicate that in spite of their age and physical condition they were still able to carry load considerably in excess of their service requirements.

The stringers in the second series of tests were 50-year-old treated stringers which had been removed from service as part of the railroad's renewal program. Upon arrival at the Research Center they appeared to be in excellent condition. The AAR had previously measured the flexural strains in these stringers under regularly operated diesel locomotives, and these strains were used in the laboratory to duplicate the service loading. A repeated load was applied to one of these stringers and at a bending stress of 570 psi, 1,000,000 load applications were made without any indication of failure by bending, shear or end bearing. The load was then increased to develop a bending stress of 2300 psi, which is approximately 50 percent in excess of the design live load not including impact. When 44,000 cycles of this load had been applied the stringer failed in horizontal shear at one end by splitting longitudinally at about mid-depth. When this happened the deflection increased from ½ in to 1⅝ in. It still maintained its load, however. The shearing stress was 170 psi. A similar stringer was then loaded statically and it carried a load seven times its service load and over twice its design load. After the stringer had failed initially, it was reloaded, but it still carried nearly the same load as before. These stringers are on display at the Research Center and I welcome you to the laboratory to see them.

Here again is indication that even though these stringers were 50 years old, they were capable of carrying static and repeated loads equal to their service loads as well

as a limited number of overloads. This also demonstrates that the repeated load strength of these stringers rather than the static strength is more indicative of their actual ultimate capacity. Furthermore, consideration must be given to shearing stresses as well as flexural stresses in evaluating these old stringers.

While it may not be possible to predict exactly how many additional years of service life are possible in these old stringers, these tests should give the bridge engineer assurance that they do have considerable reserve strength. Age alone should not be the criteria for removal of a stringer from service. With the support of Committee 7, the AAR will continue its investigation of these old bridge stringers and obtain data which will enable the Committee to make recommendations for better evaluating their strength.

Thank you. [Applause]

CHAIRMAN SCHNEIDER: Thank you, Mr. Drew. Your remarks should answer some of the questions as to the remaining life of old timber stringers, which has been of utmost concern to many bridge engineers.

As Mr. Drew told you, we are presently testing old timber stringers under repeated loads in the AAR laboratory for one of our assignments and hope we will be able to give you additional information in the near future.

Mr. President, this concludes our report.

PRESIDENT MEYERS: Thank you, Mr. Schneider. I don't know whether the members know it or not, but Mr. Schneider carried the load for this committee during most of his term as vice chairman and then accepted the chairmanship not too long ago when it was necessary for the chairman to resign. You have the appreciation, I am sure, of the entire Association membership.

I want to thank Mr. Drew for his presentation with regard to the serviceability of old bridge stringers. I could say some more about your committee, but will now excuse you with the thanks of the Association.

Discussion on Masonry

[For report see pp. 473–496]

PRESIDENT MEYERS: Will Committee 8 please come to the platform.

I would like to inform everybody that it will be necessary to close the meeting promptly at 12 o'clock, regardless of where we are, or who is speaking. I would appreciate it if you would then move up promptly to the Ballroom for the Annual Luncheon.

Also, the program shows that the afternoon session is to reconvene at 2:30. Because we are running behind schedule, I would like to move that up a little and start the session about 10 min after the luncheon session closes. I am hopeful that we can get started about 2:15.

The chairman of Committee 8 is E. A. McLeod, assistant bridge engineer, New York Central System, New York. Mr. McLeod if you are ready, you may proceed.

CHAIRMAN E. A. MCLEOD: Mr. President, members of the Association, guests:

Committee 8—Masonry, is reporting on three assignment. The reports will be found in Bulletin 547, December 1958, starting on page 473. Following the presentation of the reports there will be an illustrated talk by our guest speaker.

Assignment 2—Design of Masonry Structures, Collaborating with Committees 1, 5, 6, 7, 15, 28, and 30.

CHAIRMAN MCLEOD: J. U. Estes, associate bridge engineer of the Louisville & Nashville Railroad will now present the report on Assignment 2.

J. U. Estes: Mr. President, members, and guests:

Your committee recommends the adoption of the revisions and additions to certain Manual material, as indicated on page 474 of Bulletin 547. Mr. President, I move that these revisions be adopted.

[The motion was duly seconded, was put to a vote, and carried.]

Mr. Estes: Your committee also presents as information a tentative draft of "Specifications for Design and Construction of Reinforced Concrete Trestles for Railway Loading," as shown on pages 475 to 488, incl., Bulletin 547, to replace the previous specifications adopted in 1936 under Part 9, which have been temporarily withdrawn.

There is now a great need for such specifications in the Manual to help standardize practice and act as a guide in problems of design and construction. The specifications cover all important features of design and construction for concrete panel lengths of 14 to 22 ft, and several different types of bents.

I wish to acknowledge the great amount of work by members of the AAR research staff, and the valuable suggestions of the collaborating committees, in the preparation of these specifications.

These specifications are presented as information, with an invitation for comments and criticisms before again presenting them in 1960 for approval and publication in the Manual.

This concludes the report on Assignment 2.

President Meyers: Thank you, Mr. Estes.

Assignment 5—Tunnel Linings: Design, Construction, and Maintenance, Collaborating with Committees 1, 5, 17, 28, and 29.

Chairman McLeod: G. H. Dayett, Jr., assistant maintenance engineer, Baltimore & Ohio, will present the report on Assignment 5.

G. H. Dayett, Jr.: Mr. President, members, and guests:

Your committee submits its report in two parts.

Part one is a bibliography on tunnel repairs and is presented as information. Some of the subjects covered by the bibliography are roof bolting, general repairs, pressure grouting, reinforced concrete lining, fire and repairs, and enlarging tunnels.

Part two presents the "Specifications for Lining Railway Tunnels with Timber" for reapproval with revisions. The revisions consist of requiring timber treatment to conform to the requirements of Committee 17—Wood Preservation, deletion of a requirement for a specific construction allowance for settlement and a number of relatively minor changes in the drawings showing details of timber lining.

Mr. President, I move that these specifications be reapproved as revised.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 7—Quality of Cement and Mortars, Collaborating with Committee 6.

Chairman McLeod: R. A. Ullery, assistant to chief engineer, Bessemer & Lake Erie Railroad, will present the report on Assignment 7.

R. A. Ullery: Mr. President, members, and guests:

The use of fly ash either as an admixture or as a replacement for concrete in heavy construction work has been known for some years. However, some railroads are not too well acquainted with its possibilities, and it is for this reason that your committee prepared the first Association report on this subject as information.

The report defines fly ash, describes its characteristics, its history, its uses, its advan-

tages and disadvantages, and lists certain precaution that should be observed for good results.

A comprehensive bibliography, covering the past ten years, is included for reference.

PRESIDENT MEYERS: Thank you, Mr. Ullery.

CHAIRMAN MCLEOD: The Masonry committee feels very fortunate in being able to offer to you as a special feature an illustrated talk on "Prestressed Concrete In Western Europe and Russia," by Ben C. Gerwick, Jr., president of Ben C. Gerwick, Inc., San Francisco. Mr. Gerwick.

Prestressed Concrete In Western Europe and Russia

By Ben C. Gerwick, Jr.
President, Ben C. Gerwick, Inc.

Last May a delegation of American engineers was invited by the Academy of Construction and Architecture of the U.S.S.R. to visit the Soviet Union to inspect the prestressed concrete industry there. Our trip was timed so that we could also attend the international conference on prestressed concrete held in Berlin.

I was greatly impressed by the extensive utilization in all the European countries of prestressed concrete in buildings, bridges, and a wide variety of industrial uses.

I believe you have had a previous report on prestressed railroad bridges in Europe by Mr. Ruble. His observations and studies have been of great value to those of us who are engaged in the manufacture of prestressed concrete here in the United States.

German and French engineers have made tremendous strides in the construction of prestressed concrete railroad and highway bridges. West Berlin for example is in a feverish state of reconstruction and new construction. One of the most urgent tasks is that of building a direct subway line connecting the three western sectors. As it is now, the lines are all radial, with the center located in East Berlin. This construction is being almost entirely carried out in prestressed concrete. Of similar political importance is the construction of sewage treatment plants in West Berlin, since the old disposal beds are in what is now East German territory. Beautiful pear-shaped tanks, 150 ft high, are being built in prestressed concrete, showing a freedom of design that nevertheless meets the strictest considerations of economy.

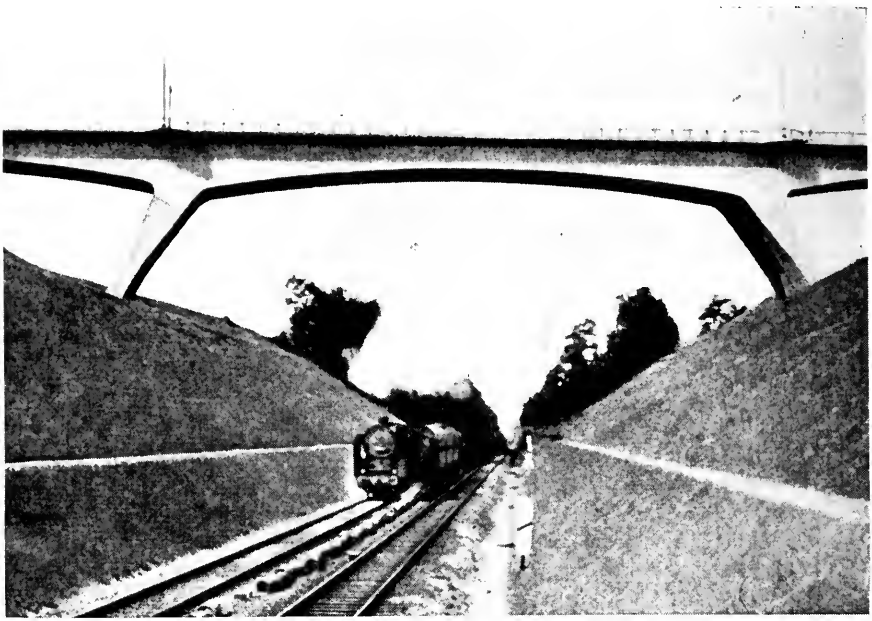
A "ring" freeway around the center of Berlin has a great many viaducts and bridges over railroads and canals. One of the largest of all these bridges is now under construction by the cantilever method of prestressed concrete construction that eliminates the need of falsework.

Substantially all of the German construction is cast-in-place and then post-tensioned. Each of the major contractors has his own patented system of post-tensioning and anchorages.

The new railway station at Heidelberg utilizes prestressed thin shells very effectively, as well as prestressed light standards. Prestressed railroad ties of several different types are in quite extensive use throughout Europe.

There have been some difficulties experienced with grouting of post-tensioned cable ducts, primarily due to freezing. The problem seems to be that small pockets of water are entrapped in the ducts when the grout is pumped in. There is a coordinated study of this subject by the engineers of several nations. The matter is particularly difficult of complete solution because it depends so much on the technique of the field personnel.

For this and other reasons there is a decided trend in Europe to the placing of the tendons externally on the member, in grooves, and then encasing the tendons in con-



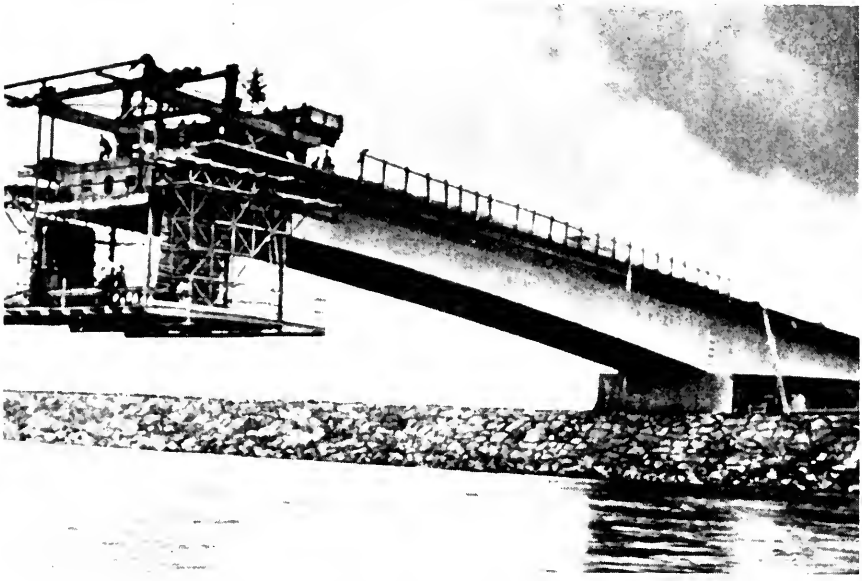
Prestressed concrete highway bridge in West Germany.

crete. Such a system permits accurate inspection of the cables after placing and again after stressing. Since no ducts have to be formed, the web members can be much thinner and lighter. Friction losses are reduced because of complete elimination of the "wobble" effect of the duct. Shear is transferred to the web by mild-steel stirrups. The final encasement can be carefully controlled and inspected.

To meet similar considerations here in the United States, many manufacturers are now producing bridge girders by the pretensioning method, using deflected strands. I personally feel this is the superior method for all girders which are capable of being precast; i.e., for all except very long-span bridges.

Engineers from several countries, notably England, advocated the use of this external post-tensioning combined with precast concrete units for long span bridges. These units are precast in short lengths, are erected on falsework and joined by the welding of mild steel reinforcing bars with either grouting or a cast-in-place plug; then the external post-tensioning is performed. We saw this system used in Russia on the main span of the Moscow River Bridge, which carries highway traffic on its upper deck and subway trains on its lower deck, with a station at mid-span. We were told that bridges of similar concept were being built across two of the large rivers in Siberia.

In Russia we found a highly developed prestressed concrete industry. Substantially all construction is based on the principle of factory-produced prestressed concrete elements. The primary construction effort in Russia today is that of housing. In Moscow and Leningrad the skyline everywhere shows apartments in the process of construction. Some 25 factories in Moscow and 15 in Leningrad manufacture standardized precast



Cantilever method of constructing prestressed concrete bridges, Rhine River, Germany.

Prestressed concrete light standards and passenger sheds at railway station, Heidelberg, Germany.

Prestressed concrete conveyor bridge, Stockholm, Sweden.

concrete floor, wall, and roof slabs. These are transported to the site by truck, and erected by welding and grouting.

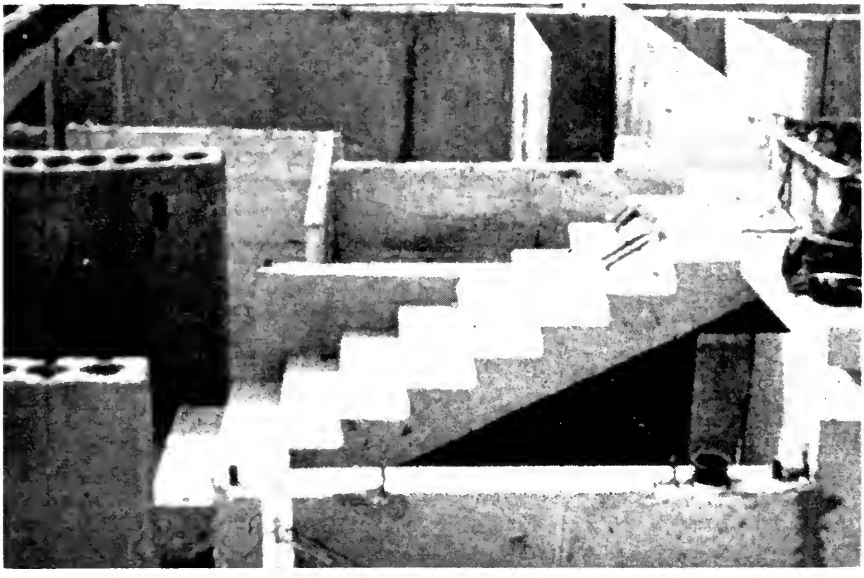
The Russian industry was quite well integrated. It comprised extensive research and development, engineering and architectural design, factory production, and field construction.

The typical Russian factory is set up for mass production of one or two standardized units. Its capacity is very large, about 200,000 cubic meters per year when running at full volume. Most of those we saw were running at about 50 percent capacity. The plant is elaborately mechanized, featuring continuous prestressing by means of wrapping the high-strength wire around pegs under tension. Individual steel frames on a chain conveyor carry the product through the production processes.

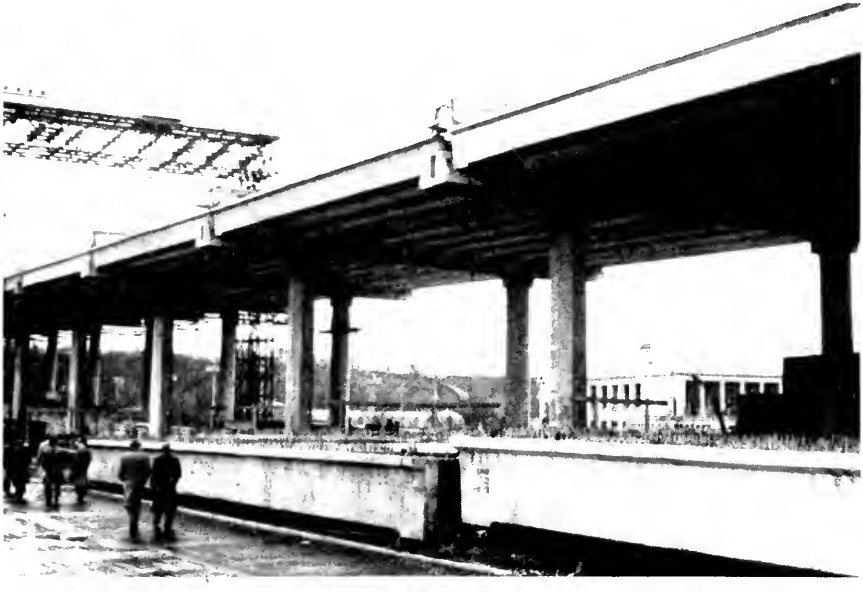
The Russians are using rectangular frames as ties for subways and railroads. These frames can be mass-produced by the same method as the building units described above.

Although the units produced by the Russian factories lacked the high quality and excellent appearance we demand and obtain, there is nothing basically wrong with the method. It showed the tremendous possibilities that can be attained by standardization and mass production of prestressed concrete.

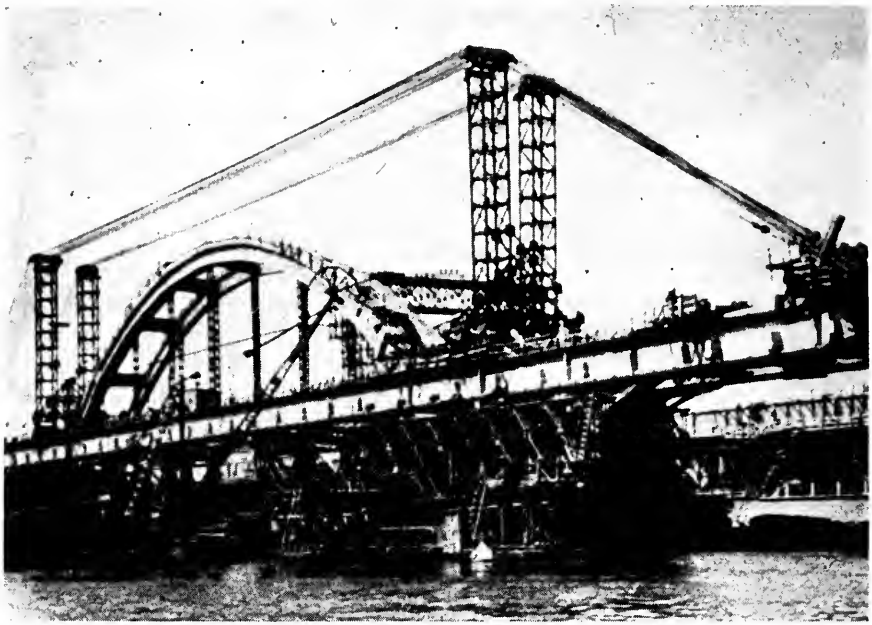
I have some slides of some of the more interesting structures in prestressed concrete which I would like to show you now.



All elements of apartment houses in Russia are factory-made precast and prestressed concrete, including stairs, vents (vertical panels with cored holes), partition and bearing walls, floors and roofs, and even spread footings.



Precast prestressed approach to Moscow River bridge.



Main span of prestressed concrete bridge across Moscow River, USSR, being floated into position.

[Mr. Gerwick showed some 42 slides, commenting on each, but only a few are reproduced herein.]

While the methods and applications of prestressed concrete vary rather widely from country to country, there is everywhere a tremendous surge of growth to the point that prestressed concrete is now the dominant structural material in Europe. The developments in Western Europe and Russia, although hastened there by special economic considerations, nevertheless portend a continued steady and sound growth of prestressed concrete in the United States. Thank you. [Applause]

CHAIRMAN MCLEOD: Thank you, Mr. Gerwick, for an interesting and informative discourse and the excellent pictures.

Mr. Woolford, this concludes the report of Committee 8.

[Vice President Woolford assumed the chair.]

VICE PRESIDENT WOOLFORD: Thank you, Mr. McLeod, and members of your committee, for a most valuable and informative report including the specifications for design and construction of reinforced concrete trestles for railroad loading and several significant revisions in our present Manual material.

The Association wishes to thank Mr. Gerwick for his excellent address. We appreciate your telling us, Mr. Gerwick, about the developments, the manufacture and use of prestressed concrete in Western European countries, Russia, and Germany. The more we learn about this development, the sooner with confidence we can make use of it on our American railroads where it proves advantageous.

Had it not been for you and your committee who visited Communistic Russia, I am afraid most of us in this country would have doubted what we hear about the progress of prestressed concrete in Russia.

As you know, most of us are a little doubtful of what the Communist nations can do, or at least what they tell us. I think we can certainly take what you have told us as being realities. I certainly do for one, as I know you do and several in your committee that made the trip to Russia.

Mr. McLeod, your committee is now excused with the thanks of the Association. [Applause]

Discussion on Impact and Bridge Stresses

[For report see pp. 379–384]

[Vice President Woolford presiding.]

Vice President Woolford: Our next report will be that of Committee 30—Impact and Bridge Stresses, of which D. S. Bechly, assistant to engineer of bridges, Illinois Central Railroad, is completing his third year as chairman.

Mr. Bechly, we will be glad to have you and other members of your committee come to the platform promptly and give your report. Gentlemen, may I ask that you be as quiet as possible so that Mr. Bechly can proceed with his report.

Chairman D. S. Bechly: Mr. President, members of the Association, and guests:

Before proceeding with the presentation of our report, this committee wishes to express its sorrow in the death of one of its members during the past year. He was Professor W. M. Wilson, emeritus research professor of structural engineering at the University of Illinois, and Member Emeritus of Committee 30. A memoir in honor of Professor Wilson will be included in the report of Committee 15—Iron and Steel Structures.

In gathering together my thoughts for this report, the perhaps misleading name of this committee caused me to pause and think a minute. Impact! That is the first word you see in the name, and to many members and other railroad men it brings forth the conclusion that we spend all of our time—and money—studying only this problem. In fact, I have heard the question raised that it would seem that we should have this item all figured out by now. Even the word "Impact" is a misnomer. Our study in this field is really with regard to the dynamic effect of moving loads on railroad bridges. That is, trains moving across the bridges, not being dropped on them!

At the time of the formation of Committee 30, impact was the principal feature to be studied, and we are continuing to do so, not only for steel girder spans and trusses, but also for timber and concrete bridges, and, of late, for prestressed concrete structures. The field has also diverged to cover diesel locomotives and rolling loads, as well as the once familiar reciprocating steam locomotive. Knowledge of the correct impact percentage has become increasingly important in the rating of existing bridges for the passage of heavily loaded cars.

It appears to me, however, that the second portion of the committee's title, "Bridge Stresses," now constitutes the major feature of our work. We are working towards an understanding and evaluation of the stresses in all types of railroad bridge structures—girders, trusses, beam spans, floor systems, continuous bridges, substructures, timber trestles, prestressed concrete beams, and glued laminated timbers, to name the items that come to mind. This work covers not only impact stresses, but also dead- and live-load stresses, distribution of stress, relation of actual stress as measured in the field to the calculated stress, duration of stress, and the effect of repetetive loading, or fatigue stress.

One new assignment, which is reported on for the first time this year, deals with the newest tool which structural engineers are using for design calculations . . . the electronic computer. The Committee also maintains a close contact with structural research being carried on by other organizations.

I hope that this has given you an idea as to the scope of Committee 30's work. These investigations are carried out with the cooperation of the staff of the AAR Research Center, and in collaboration with the other structural committees of the AREA. A good portion of our work is done at the request of these committees, and the results are used by them in the preparation of new or revised specifications. It is the intention of the members of this committee that these investigations will result in savings in construction and maintenance costs for the American railroads.

Nine of the committee's 11 assignments are reported on this year in Bulletin 547, pages 379 to 384. These are progress reports, and are presented as information. These reports will not be dealt with directly today, and you are referred to the Bulletin for specific information as to the progress during the past year. I would now like to comment briefly on these assignments.

Assignment 1—Steel Girder Spans.

CHAIRMAN BECHLY: A summary report on the complete series of tests covering 37 steel girder spans, which have been made over the past several years, is in preparation, and should be completed for publication this year. This report compares these girder spans as to the effect of their length, type, standard of design, type of floor, and loading. When completed, it will increase our understanding as to the behavior of girder spans. One obvious conclusion that has already been drawn is that the current impact formula for girder spans is quite adequate. This feature is being given further study toward a recommended revision in the impact formula.

Assignment 3—Viaduct Columns.

CHAIRMAN BECHLY: Data on the behavior of viaduct columns is continually being collected in connection with our tests on railroad bridges. This data have been reported from time to time, and it is the committee's plan to continue this practice until such time as sufficient information has been gathered to present a comprehensive final report on these columns.

Assignment 4—Longitudinal Forces in Bridge Structures, Collaborating with Committees 7, 8 and 15.

CHAIRMAN BECHLY: As in the case of Assignment 3, data on this assignment are also being collected during our field tests. The latest information obtained was during the tests on the timber trestles on the Seaboard Air Line Railroad, reported on under Assignment 7. In these tests, as in previous ones, it was found that the preponderance of the longitudinal force was carried off the structure by the rails.

Assignment 5—Distribution of Live Load in Bridge Floors.

CHAIRMAN BECHLY: The current project under this assignment is a study of railroad bridge floor systems at the University of Illinois. Comparisons are now being made of the results of their analytical analysis with the data obtained in previous field tests. This program is directed toward the development of a simplified procedure for calculation of stresses in bridge floors. It is of interest that the university is using its digital computer in this work to make it possible to include all of the variable factors in its analysis.

Assignment 6—Concrete Structures, Collaborating with Committee 8.

CHAIRMAN BECHLY: All of the work currently in progress on concrete structures is in the field of prestressed concrete. Our report on this assignment covers theoretical and laboratory investigations of the fatigue resistance of prestressed pretentioned concrete beams, which were conducted at Lehigh University. These tests were set up to prove that ½-in strands will perform satisfactorily under a large number of repeated loads. The performance was verified, and plans are presently under way to continue this study to substantiate these findings and to extend the range of the investigation.

Also in the field of prestressed concrete, field testing has been completed on spans consisting of 70-ft post-tensioned girders on the Santa Fe Railway, and on a double-track concrete trestle on the Southern Railway having 26-ft spans consisting of 6 hollow rectangular pretensioned beams per track.

Assignment 7—Timber Structures, Collaborating with Committee 7.

This is the first report under this assignment on tests conducted specifically on timber trestles. The report covers the investigation of two ballasted deck pile trestles on the Seaboard Air Line. These bridges were selected because of the relatively high humidity in the area, which resulted in the moisture content of the timber being above fiber saturation. These tests indicated that the decks of trestles having alternate stringers which are continuous over the bents act as a partially continuous structure.

In the test program on these trestles not only was the magnitude of the stresses measured, but also their duration. The results of this study are included in the report, and it is interesting to note that the cumulative effect of loading from the cars may be of greater importance than that from the diesel locomotives.

A report on similar tests of four ballasted-deck pile trestles on the Santa Fe is nearing completion. These trestles are located in Arizona, and were selected to obtain the comparative effect of an arid atmosphere. It is next planned to extend this test series to include open-deck pile trestles.

Timber bridges constitute roughly 40 percent of all of the railroad bridges in the United States. They have a combined length of about 1800 miles. Multiplied by this vast number of bridges, an improvement in this type of structure will be of appreciable benefit to the railroads. For this reason, we feel that our investigation of these timber trestles is one of the most important studies being made by Committee 30.

Assignment 8—Vibrational Characteristics of Bridges Affecting Deflections and Depth Ratios.

CHAIRMAN BECHLY: This is the first of four new assignments undertaken by Committee 30 this year. This one was brought about by a desire to study the effect of increasing the deflections and depth-span ratios of railroad bridges. Particularly in the field of grade separation projects has there been an interest in increasing these variables in order to permit the use of thinner floors and to promote greater economy.

An analytical study of the problem is in progress at New York University. As a part of the project, data previously secured under actual train operations by the research staff will be compared with the analytical results. It is interesting to note in this project, too, that use is being made of an electronic computer to permit the simultaneous solution of equations containing numerous variables.

Assignment 9—Use of Electronic Computers for Railroad Bridge Problems.

CHAIRMAN BECHLY: With the introduction of electronic computers into the field of engineering, it has been found that their use will save valuable time in the solution

of lengthy or repetitive problems. One such problem common to railroad bridge departments is the rating of bridges and moving loads, particularly truss bridges. As a part of this assignment, we have begun the development of a computer program for the stress analysis and rating of truss bridges subjected to moving railroad loads. Because of the shortage of necessary personnel on the Research Center staff, it was decided to contract for the development of this program. Hazelet and Erdal, consulting engineers in Chicago, have been engaged to do this work.

The first phase of this project, which is the programming to produce shear and moment tables for any given combination of wheel loads, has been completed. As an example of what can be done, such tables have been produced for a 12-axle special flat car used for the transportation of heavy shipments. This table was distributed to the chief engineers of the member roads, and because of the interest expressed, we now plan to develop similar tables for about 25 other heavy-duty cars. These tables will be distributed to the railroads, and should provide valuable assistance in the speedy checking of these cars for movement over bridges.

Assignment 10—Steel Continuous Structures, Collaborating with Committee 15.

Field testing has been completed on three bridges having continuous steel spans on the Southern Pacific. A three-span deck truss bridge, a three-span deck girder bridge, and a two-span through girder bridge are included in this project. Analysis of the data has been completed, and preparation of the report is under way.

This completes a brief resumé of the current work of Committee 30. In order to acquaint you with some of the men who are responsible for the committee's activities, I would now like to introduce the subcommittee chairmen. As I give their names, I ask that each chairman stand, in order that he may be recognized.

M. J. Plumb, Plumb, Tuckett & Pikarsky, Consulting Engineers, Subcommittee on Steel Girder Spans

E. S. Birkenwald, engineer of bridges, Southern Railway System, Subcommittee on Steel Truss Spans

Dean A. T. Granger, College of Engineering, University of Tennessee, Subcommittee on Viaduct Columns. Mr. Granger was not able to be present.

J. A. Erskine, assistant bridge and building engineer, Gulf, Mobile & Ohio Railroad, Subcommittee on Longitudinal Forces. Also not present.

Dr. N. M. Newmark, Department of Civil Engineering, University of Illinois, Subcommittee on Distribution of Live Load. Not present.

P. L. Montgomery, assistant designing engineer, Nickel Plate, Subcommittee on Concrete Structures.

C. V. Lund, assistant to chief engineer, Milwaukee Road, Subcommittee on Timber Structures. Mr. Lund had to be out of town today.

Dr. James Michalos, Department of Civil Engineering, New York University, Subcommittee on Vibrational Characteristics. Not able to be present.

E. R. Andrlik, bridge designer, Santa Fe Railway, Subcommittee on Electronic Computation.

A. R. Harris, engineer of bridges, Chicago & North Western Railway, Subcommittee on Continuous Structures.

N. E. Ekrem, assistant bridge engineer, Great Northern Railway, Subcommittee on Composite Design. Mr. Ekrem is not here.

Thank you, Gentlemen. In that I am at this time completing my term as chairman of Committee 30, I would like to express my appreciation for the assistance you have given to me during the past three years. My thanks, also, are extended to the members of the committee, and to the staff of the Research Center for their cooperation during this period.

At this time, I would like to introduce the new vice-chairman of Committee 30. He is J. W. Davidson, assistant bridge engineer of the Burlington Railroad.

I would now like to introduce D. W. Musser, design engineer, Erie Railroad, who will become the new chairman of Committee 30. Mr. Musser has been an able assistant during my term of office, and I am certain that he will do an excellent job of administering the affairs of the committee.

Mr. Woolford, this concludes the report of Committee 30—Impact and Bridge Stresses.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Bechly. We certainly appreciate the interest your subcommittee chairmen have taken in this most important subject. Year after year your committee carried forward many important investigations and tests which have an important effect on bridge design and on more economical bridge construction and maintenance. I know how important these special studies and investigations are to the work of our other structural committees, and to the structural men on individual railroads.

I congratulate your committee upon its work during the past year, and you upon the able direction which you have given to the committee for the past three years. We welcome Mr. Musser as the new chairman of your committee, and Mr. Davidson as the new vice chairman. I am sure we can look to them to continue the effective work which has been done by your committee in the past.

Your committee is now excused with the thanks of the Association. [Applause]

Discussion on Iron and Steel Structures

[For report see pp. 505–553]

[Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: Gentlemen, it is getting pretty close to the time for our Annual Luncheon. I am going to ask Mr. Messman, who is the chairman of Committee 15, now coming to the podium, if he would like to start his report now or wait until after the noon luncheon.

D. V. MESSMAN: Let's start now.

VICE PRESIDENT WOOLFORD: Fine, sir. Will Committee 15 members come to the podium.

The last of our structural committees to report this morning is Committee 15—Iron and Steel Structures. The chairman of this committee is D. V. Messman, engineer of bridges, Central Lines, Southern Railway System, Knoxville, Tenn., who is completing his first year as chairman.

CHAIRMAN D. V. MESSMAN: Mr. Woolford, members of the Association, and guests:

Your Committee on Iron and Steel Structures is reporting on seven of its eight assignments. These reports appear in Bulletin 548 starting on page 505.

During the past year our committee lost one of its valued Members Emeritus, Professor W. M. Wilson of the University of Illinois and a memoir prepared subsequent to the issuance of Bulletin 548 will also be included in our presentation here.

MEMOIR

Wilber M. Wilson

Committee 15 records with deep regret the death on November 28, 1958, of a long-time member and Member Emeritus, Wilbur M. Wilson.

Professor Wilson joined the AREA in 1921 and became a Life Member in 1949. He became a member of Committee 15 in 1924, and was made Member Emeritus in 1954. Professor Wilson was also a member of Committee 30. He became affiliated with that committee in 1937, and was elected Member Emeritus in 1954.

Professor Wilson was born on a farm near West Liberty, Iowa, July 6, 1881. He received the degree of Bachelor of Mechanical Engineering from Iowa State College in 1900 and served on the staff of that institution in mechanical engineering from 1901 to 1903 and from 1904 to 1907, as instructor, assistant professor and associate professor. His alma mater conferred on him the professional degree of Civil Engineer in 1914 and the honorary degree of Doctor of Engineering in 1942. Professor Wilson also received the degree of Master of Mechanical Engineering from Cornell University in 1904, having been a graduate fellow there in 1903–1904.

Following six years of professional practice with the Illinois Steel Company and the Strauss Bascule Bridge Company in Chicago, Professor Wilson joined the civil engineering staff at the University of Illinois in 1913 and, except for a two year absence in 1917–1919 for military service, served that institution continuously until his retirement in 1949.

Professor Wilson's analytical and experimental investigations brought him world-wide renown, and greatly influenced design specifications and practice in the field of structural engineering. He was ingenious in devising methods for testing large-size structural members, and the large-capacity fatigue testing machines he developed at the University of Illinois have been copied in laboratories all over the United States and elsewhere in the world.

The last major investigation initiated by Professor Wilson may become his most important contribution to his profession. Becoming interested in more efficient structural fasteners he brought about the establishment of the Research Council on Riveted and Bolted Structural Joints, and was personally responsible for much of its early work. The investigations accomplished by the Council in the years following its founding have resulted in a remarkable increase in the use of high-strength bolts for structural connections, particularly for field connections. In some recent large bridges they have almost entirely eliminated field riveting.

Professor Wilson was active in many professional societies other than the AREA, and an indication of his contributions to their activities may be obtained from the fact that he was awarded the Chanute Medal of the Western Society of Engineers on two occasions, the J. James R. Cross Medal of the American Society of Civil Engineers and the Wason Medal of the American Concrete Institute. He received the Marston Medal from Iowa State College in 1949. He served the American Society of Civil Engineers as a director, 1944–1947 and was elected an Honorary Member of that Society in 1950.

Assignment 1—Revision of Manual.

CHAIRMAN MESSMAN: Report on Assignments 1 and 3 will be given by E. S. Birkenwald, engineer of bridges, Southern Railway System, Cincinnati, Ohio.

E. S. BIRKENWALD: Mr. President, members of the Association, and guests:

Assignment 1 concerns the revision of Specifications for Steel Railway Bridges, the revision of Rules for Rating Existing Iron and Steel Bridges and the reapproval without change of other Manual material.

Revision of four items in the Specifications for Steel Railway Bridges are submitted. The first concerns the substitution of the words "High-Strength" for the word "Alloy" in the Table of Contents, in order to be consistent with the Manual material. The second change is in the maximum span limits for plate girders and the minimum span limit for riveted trusses, to be in accord with present practice. The third concerns rivets and is a clarification which outlines what the existing specifications term "specially designed." This revision omits reference to the phrase "to fill the holes completely when driven," since cross sections made of rivets driven in plates show that this condition is rarely fulfilled. The tapered rivet specially designed in accordance with the proposed revision will provide the necessary tension in the cooled driven rivet which makes it function effectively. The fourth is a clarification necessitated by inquiry as to the shop practice desired.

I therefore move that these revisions to the Specifications for Steel Railway Bridges, listed on page 506, Bulletin 548, be adopted for publication in the Manual and that the remainder of these specifications be reapproved.

[Past President Ray McBrian assumed the chair.]

[The motion was duly seconded, was put to a vote, and carried.]

MR. BIRKENWALD: Last year revisions to Art. 14 of the Rules for Rating Existing Iron and Steel Bridges were presented to the Association as information. It now develops that certain coefficients for the column formulas and the formulas for compression in extreme fibers of rolled shapes, girders and built sections, subject to bending, for the high-strength steel need to be modified slightly to obtain values more in accord with the secant formula. These modifications are given on page 507, Bulletin 548. Attention is called to the term l^2r^2 in third line. This term should be l^2/r^2.

I therefore move that the Rules for Rating Existing Iron and Steel Bridges be reapproved, including the adoption of the revisions for Art. 14 set forth on page 507 of the Bulletin, with the modification just mentioned.

[The motion was duly seconded, was put to a vote, and carried.]

MR. BIRKENWALD: The following Manual material, listed on pages 506 and 507, is due for reapproval without change:

Specifications for the Design of Rigid-Frame Steel Bridges.
Instructions for the Mill Inspection of Structural Steel.
Instructions for the Inspection of the Fabrication of Steel Bridges.
Instructions for the inspection of Bridge Erection.
Classification of Railway Bridges.
Fusion Welding.
Track Anchorage on Bridges and Similar Structures.
Method of Shortening Eyebars to Equalize the Stress.

Each of these items has been reviewed and the committee has taken a letter ballot, in which more than a two-thirds majority favored reapproval without change.

I therefore move that the Manual material, set forth on pages 506 and 507, be reapproved without change.

[The motion was duly seconded, was put to a vote, and carried.]

MR. BIRKENWALD: This concludes the report on Assignment 1.

Assignment 3—Specifications for Use of High-Strength Steels.

MR. BIRKENWALD: In connection with Assignment 3, the Association last year adopted a specification for the use of high-strength steel. A study of the column formulas and the formulas for compression in extreme fibers of rolled shapes, girders, and built sections subject to bending indicated that the coefficients needed modification to be consistent with the application of the secant formula. These changes are given on page 508.

I therefore move that those changes in coefficients, outlined on page 508, be adopted for publication.

[The motion was duly seconded, was put to a vote, and carried.]

MR. BIRKENWALD: Since the committee has completed its work in preparing the specifications for use of high-strength steels, the committee recommends that Assignment 3 be now terminated.

This concludes the report on Assignment 3.

PAST PRESIDENT MCBRIAN: Thank you, Mr. Birkenwald.

Assignment 4—Stress Distribution in Bridge Frames: (c) Model Railway Truss Bridge.

CHAIRMAN MESSMAN: Report on Assignment 4 (c) will be given by C. H. Sandberg, bridge engineer system, Atchison, Topeka & Santa Fe Railway, Chicago.

C. H. SANDBERG: Mr. Chairman, gentlemen:

This assignment has to do with stress distribution in bridge frames.

During the past year the committee has been mostly concerned with our truss bridge research project. This is a joint project sponsored by the AAR, Northwestern University, the Army Engineers, and the Bureau of Public Roads.

During the year the steel building was erected enclosing the truss. Erection has also been started and is nearly completed of the hydraulic jacking system. The first members to be tested will be the batter posts. These test members are in place and stress gages have also been put on. These tests will be started shortly.

This report is presented as progress.

PAST PRESIDENT MCBRIAN: Thank you, Mr. Sandberg.

CHAIRMAN MESSMAN: Mr. McBrian, I think we have used all our time this morning. We will recess until this afternoon.

PAST PRESIDENT MCBRIAN: We will now stand recessed for the Annual Luncheon, to reconvene at 2:30.

[The meeting recessed at 12 o'clock.]

Annual Luncheon

Grand Ballroom—12 Noon
Tuesday, March 10, 1959

[The Annual Luncheon was held in the Grand Ballroom with a background of organ music. At the main Speaker's Table were seated executives of various railroads and past and present officers of the Association. At a long table immediately in front of the main Speaker's Table were seated the chairmen of the Association's 23 standing and special committees.

After the Luncheon, those assembled sang the National Anthem, following which President Meyers introduced those at the main Speaker's Table and then those at the

Chairmen's Table. He also introduced the incoming committee chairmen, who were given gavels. Then, after announcing the results of the election of officers (see Tellers Report appearing on page 982), President Meyers introduced the speaker at the Luncheon —Mr. Ben W. Heineman, chairman, Chicago & North Western Railway.]

Economics of Railroads Today

By Ben W. Heineman

Chairman, Chicago & North Western Railway

[In introductory remarks to his prepared address, Mr. Heineman, as a special announcement—which came as a surprise both to President Meyers and others attending the Luncheon—stated that on the preceding Thursday—March 5—the Board of Directors of the Chicago & North Western Railway had elected Mr. Meyers vice president and chief engineer of the North Western, and had kept it a secret so the announcement could be made at the time of the Annual Luncheon.]

Mr. Chairman, members of the AREA, and guests:

It is an honor to be invited to discuss with so distinguished and influential a group the economics of railroads today. None of you will make the mistake of thinking that this subject is abstract or removed from your daily preoccupations.

You, of all people in the industry, are aware that whether and how well we solve our economic problems will directly determine whether and how well you will be able to discharge your own present and future responsibilities. For our engineering departments are truly the economic litmus paper of our industry. You are the first to reflect the chemical effects of retrenchment and lack of funds.

No analysis of our economic problems can be meaningful without recognizing that the single most conspicuous economic fact about the railroad industry is the existence under its private ownership of a vast, irreplaceable steel highway reaching into every nook and cranny of the United States.

There are some 220,000 miles of railway line in the Continental United States. This represents only the total point-to-point length of the railroads and does not include yard track, sidings or multiple track; if these were included, another 170,000 miles of railroad would be added.

It is unnecessary for me to tell you that this is a lot of railroad. You know it better than I, for you have walked it, maintained it and been responsible for it. Its dimensions are staggering. Compare it for example with the mileage of the federal aid primary highway system. This system connects all of the principal cities, county seats, ports, manufacturing and other traffic generating areas in the United States. In general, it is also the main state trunk line system. And yet the total extent of the federal aid primary highway system is but 235,000 miles.

Now there are many fascinating facts and statistics that could be compiled about this huge railroad network: the numbers of ties, the pounds of steel, the yards of ballast, the feet of bridges, or the number of frogs, switches and crossings. Or perhaps the number of miles of railroad-owned pole lines or wire for signals or communications paralleling substantially its entire length.

Or one could approach the analysis by considering such matters as the maintenance cost or the tax cost per mile of track or road, all borne by the privately owned railroads of the United States.

Yes, the possibilities for statistical analysis of the components of our rights-of-way are numerous. And yet, valuable and instructive though such analyses may be for some

purposes, they tell us no more about the function and potential of our rights-of-way than we would learn about the capacities of a human being by being told that within the body there are 206 bones, 32 teeth, 10 pints of blood and millions of specialized cells.

For just as the human being is infinitely more than the sum of his individual parts, so in our right-of-way do we have a highly efficient and specialized tool that is in total infinitely more than the wood, metal and stone that comprise it. By its mere existence, it provides *the* dominant fact of our industry's economic life, and certainly *a* dominant fact of our nation's.

That this is an efficient tool has been fully demonstrated over a period of more than 100 years. But this tool—this fixed plant—efficient though it may be, is today seriously under-utilized, to the detriment of both the railroads and the consuming public.

Since 1940, there have been only three years in which our revenue ton miles were as low as in 1958 estimates, and there was no year in that period, including the war years, when it could have been said that our fixed plant was operating at capacity. The mere fact of dieselization, with its longer trains and fewer freight train miles, has materially increased the existing capacities of our right-of-way. And through centralized traffic control, technical means are at hand to increase this capacity still further and at will, and at a relatively low cost per mile of road.

It is facts such as these that have led many students of transportation economics to the conclusion that one of our industry's major problems is excessive fixed plant or right-of-way. To some, these conclusions are fortified by the apparent inability of the railroads to participate proportionately in the expansion of our economy. For although the volume of all inter-city freight hauled by all carriers has more than doubled between 1940 and 1957, the railroads' volume in absolute terms increased by only 50 percent, and, except for a period of war-time rubber and gas rationing, our proportion of the whole has diminished in every year.

Now, if the market or need for our services—for transportation services—had been diminishing, then this pessimism might seem justified. But the hope, the challenge, and the opportunity lie in the fact that the demand for transportation services—our markets—have been steadily increasing. And this is true even if we wholly exclude all traffic handled by so specialized a carrier as the pipeline. And the next 15 years will bring an increased demand for transportation services that will exceed our fondest hopes.

Yes, the markets are there and growing. All that is necessary is that we have the courage and vision to recapture them.

Improvement in service through faster and safer handling and increasing and more specialized equipment, we may take for granted. At least it is not my purpose to discuss it here. But better or improved service, essential though it is, and come though it must, is by no means the only or principal answer.

For our markets will be regained only through price. For it is price that moves goods. It moves goods in volume from the shelves, and it moves goods on the transportation highways of the world.

It follows that, in my opinion at least, the railroads, for the indefinite future, must resist every temptation to increase their rates, regardless of inflationary pressures, and must seek to reduce their rates wherever possible.

The truckers, who (apart from the specialized pipelines) have made the greatest gains at the railroads' expense, regularly maintain their rates at levels under those of the railroads. It may be conceded that there are shippers who need the greater speed and flexibility of the truck, but there are countless shippers who utilize the truck not because they genuinely require the greater speed and flexibility, but because they are

able to get these attributes for nothing as part of a price structure lower than that charged by the railroads.

Of course, there is a definite need for the truck in our economy. I know of no railroad that would contend otherwise. But there is also a genuine need for a realistic price structure under which those who genuinely require the greater speed and flexibility of the truck would pay a premium for it over a lower railroad rate structure.

The railroads have too long sheltered their competitors. Moreover, this sheltering process has been uneconomic, not based on any reasonable estimate of costs, and at the expense not merely of the railroads, but of the public and the consumer.

It is a characteristic—a most important characteristic—of railroad operations that our incremental costs do not increase anything like in proportion to our incremental revenues. This is due in part to the under-utilization of our existing fixed plant, and also due in part to the ability of railroads, unique in the transportation industry, to multiply load without a proportionate increase in the direct costs of transportation.

For a generation, we in the railroad business, and I include those who regulate us, have been the victims of a price neurosis. Although for a generation the railroads have been engaged in one of the most highly competitive businesses in the country, we have responded automatically and without regard to competitive factors, to wage and material increases by seeking ever higher and higher rates, while at the same time retaining costly services having no current economic justification.

The railroads' function in our economy today is that of volume transportation. Neither in the hauling of goods nor of people is there any basis for custom-tailored or highly specialized transportation, unless it be solely for promotion or advertising purposes. It is our function—in my opinion, it is our duty—to haul ever increasing volumes of goods at the lowest possible prices.

If the railroads had carried in 1957 their 1950 proportion of the total revenue freight available in 1957, and had carried it at their 1950 rates, their operating revenues in 1957 would have been nearly a billion dollars more than they were.

It can not be questioned, in view of the excess capacity of our fixed plant and our ability to carry additional volume at decreasing unit costs, but that both the railroads and the public would have been far better off.

Regulatory agencies were initially provided with rate-making powers for one purpose and one purpose only—to fix maximum prices to protect the public against the danger of exorbitant prices that might be established by a monopolistic railroad transportation system. But with the fantastic growth of competing forms of transportation, such dangers have long since disappeared.

It is perhaps not as surprising to find competitors who have in the past generation increased their proportion of an ever-increasing volume from 32 percent to 54 percent at the expense of the railroads, using their political and regulatory influence to resist rate *decreases* by the railroads for fear, or so they say, that they may put them out of business.

Not all attacks upon rate reductions by railroads are direct; many are oblique. Some proceed by way of placing upon railroads the burden in advance of proving beyond all reasonable necessiity that the proposed rate reductions are not in fact below their actual costs.

This is indeed a slippery concept. The theoretical foundations of railroad costs have not even been agreed upon. Even if the theoretical foundation of railroad cost determinations had been laid, it would take not one but a dozen lifetimes to establish in quasi-

judicial proceedings the costs of hauling particular commodities under the thousands of rates in effect throughout the county.

As a matter of fact, since our unit costs diminish as our incremental revenues increase, what is bare return of cost today on a given product may be highly profitable tomorrow if the rate fulfills its purpose.

And what of the public and the consumer in today's economy? A major economic threat is inflation. Surely the interest of the farmer and of labor and the consuming public in decreasing railroad rates and lower transportation costs—in short, in a decreasing cost of living—should be given the highest priority by our legislatures and regulatory agencies. And surely no obstacles should be placed in the way of a resurgent and increasingly efficient railroad industry seeking to contribute to these objectives through lower rates.

Today, however, the regulatory agency, its original rate-making purpose destroyed by the march of history, is an allocator of business, parcelling it out through the medium of minimum prices to the various modes of transportation. No government agency can effectively take the place of a market mechanism where competition exists.

I am convinced that it is in the interests of the consumer and the public for railroads to be put in the same position as all other industry in terms of rate or price making. Where railroads seek to reduce rates, I can conceive of no legitimate purpose in placing the burden intially upon them to justify such rate reductions. In my opinion, at any time, but particularly in a period of threatened inflation, there is a presumption that rate reductions are in the public interest.

There exists in all industries the possibility, infrequent in practice, that prices may be reduced below costs for predatory, monopolistic or discriminatory purposes. I see no reason why, if railroad rates are reduced for any such reasons, such complaints may not be heard subsequently, just as in any other industry.

But unfortunately, there are some that view any price reductions by railroads which have the effect or recapturing a portion of the traffic theretofore lost, as made for predatory or monopolistic purposes. Those who take such a view will never acquiesce in any railroad rate sufficiently low to regain traffic. And if this view should become the majority or legislative view, the cost will be borne by the consumer.

The full capacity of railroads to absorb inflationary pressures without increasing rates, and, indeed, their ability to lower them, has never been fully explored. If the railroads are permitted to transform their inherent efficiency into the lowest possible rates, in part through realizing the benefits of increased volume, in part through the reduction of costs by the elimination of service that has become economically obsolete and unneeded, and in part through the modernization on a fair and equitable basis of existing labor contracts, the consumer will be the immediate and direct beneficiary, the railroads will once more be participating proportionately in the growth of the country, and we no longer will regard excess in fixed plant as a major concern. [Applause]

Afternoon Session—March 10, 1959

[The meeting reconvened at 2:15 o'clock, Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: Will the meeting please come to order.

We have a long program still ahead of us this afternoon. It is important that we get started on time and keep the show on the road if we are to close this session anywhere near on time today.

I ask each chairman to adhere strictly to his time schedule, allowing a few minutes for any comments or discussions from the floor.

Discussion on Iron and Steel Structures (Continued)

VICE PRESIDENT WOOLFORD: Just before lunch we had Committee 15 on the podium giving their report. Will Mr. Messman please continue.

Assignment 6—Preparation and Painting of Steel Surfaces.

CHAIRMAN MESSMAN: We now come to the report on Assignment 6 which will be given by R. C. Baker, engineer of structures, Chicago & Eastern Illinois Railroad, Danville, Ill. Mr. Baker.

R. C. BAKER: Mr. President, members and guests:

The original assignment on this subject dates back to before 1946, the original assignment having been inaugurated to report on the flame cleaning of steel. Flame cleaning of steel was publicized very highly during the 1940's and is still used today for special work, but it did not prove to be the final answer to the problem of surface preparation for painting.

In 1947 the assignment was changed to read "Preparation of Steel Surfaces Before Painting."

In 1949 a request was made to the AAR by a Member Road for a reseach project to be inaugurated to determine means for removing paint from steel, presenting to the AREA at that time a proposal from a research institute for carrying out this work. Your Association decided that this project should be kept within the work of the AREA, but was confronted with the problem of where and how to carry out the necessary research work. In 1950 the Steel Structures Painting Council was formed, and the AREA became a contributing member in 1951.

The AAR paint test on a New York Central railroad bridge in Chicago was started in 1951 to test the suitability of a chemically cleaned and pretreated surface compared with the usual hand-cleaned surface. The chemical paint remover was very difficult to use in the field, and the results from this test refuted many of the claims for the advantages of chemically cleaned and pretreated surfaces for the repainting of steel structures.

In 1953 the assignment was changed to read "Preparation and Painting of Steel Surfaces."

I would like to call to your attention the test started this past year on the Chicago Great Western Railway, which is described in our report under the heading: "The protection of Top Flanges of Bridges and the Treatment of Welds Before Painting." We hope that this test will furnish needed information for better protection to the top flanges of our open-deck bridges.

Since it is the general opinion that there will be more welded bridges in the future, this study on the treatment of welds before painting, together with the laboratory tests now being conducted by the Painting Council, should be of great interest to the AREA.

This completes our report on this subject.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Baker.

Assignment 7—Bibliography and Technical Explanation of Various Requirements in AREA Specification Relating to Iron and Steel Structures.

CHAIRMAN MESSMAN: In the absence of E. K. Timby, consulting engineer and subcommittee chairman, the report on Assignment 7 will be given by J. M. Hayes, professor of structural engineering, Purdue University.

J. M. HAYES: Mr. Chairman, members of the Association, and guests:

Assignment 7 calls for a bibliography and technical explanation of various requirements in AREA specifications relating to iron and steel structures.

This subject grew out of a need for explaining the various parts of our specifications. This need is especially felt by younger engineers who sometimes have difficulty in interpreting the intent and limitations of our specifications.

This year's report, which is concerned with the structural sections of Chapter 15, covers the historical background of certain parts and also gives information supplemental to Manual material to help the engineer exercise judgment. A bibliography is included for those interested in further study.

The study disclosed questionable bases for a few parts in the light of present knowledge. These parts are now under scrutiny; e.g., wind loading.

Mr. Tammen, Member Emeritus of Committee 15, contributed much to the work of the subcommittee.

The material is presented as information, looking to its adoption and publication in the Manual next year as Appendix B of the Specifications for Steel Railway Bridges.

Further work on the assignment will include similar reports on material other than the structural sections.

This concludes the report on Assignment 7.

VICE PRESIDENT WOOLFORD: Thank you, Prof. Hayes.

Assignment 8—Specification for Design of Corrugated Metal Culverts, Including Corrugated Arches.

CHAIRMAN MESSMAN: In the absence of Subcommittee Chairman W. E. Dowling, assistant system bridge engineer, Union Pacific Railroad, A. R. Harris, engineer of bridges, Chicago & North Western Railway, will give the report on Assignment 8.

A. R. HARRIS: Mr. Chairman, members of AREA, guests:

The purpose of Assignment 8 is to review the specifications for metal culverts and arches and prepare such revisions or such new specifications as are considered necessary.

The current specifications for corrugated structural plate pipe were adopted in 1954 and appear in Chapter 1, Part 4 of the Manual. The material presented in this progress report is intended to bring certain portions of these specifications in line with established industry practices and to better define accepted design and field installation procedure.

The report also recommends the inclusion of specifications to cover design and installation of corrugated structural plate pipe-arch and arch forms, which are being widely used by railroads under rather shallow fills.

It is anticipated that the revisions suggested in this report will be recommended for adoption and publication in the Manual next year.

That concludes the report of the subcommittee.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Harris. Your report will be considered as information.

Assignment 10—Specification for Design of Continuous Bridges.

CHAIRMAN MESSMAN: Report on Assignment 10 will be given by J. F. Marsh, designing engineer of DeLeuw, Cather, and Company, Chicago.

J. F. MARSH: Mr. President, members of the Association, and guests:

Last year your committee presented Specifications for the Design of Continuous Steel Railway Bridges with the recommendation that they be adopted and published in the Manual. To the present time no criticisms have been received which would necessitate revisions in the adopted specifications.

The committee submits this final report as information with the request that the assignment be concluded.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Marsh. The report will be so received.

CHAIRMAN MESSMAN: The abstract of the memoir for Professor W. M. Wilson will be given by his former colleague, J. G. Clark of the firm Clark, Daily, and Dietz, Urbana, Ill.

[Mr. Clark read abstracts from the Memoir for Wilbur M. Wilson, presented at the beginning of the discussion on Iron and Steel Structures.]

VICE PRESIDENT WOOLFORD: Thank you, Mr. Clark.

CHAIRMAN MESSMAN: Mr. Woolford, unless there are any comments or questions from the floor, that concludes the report of Committee 15.

VICE PRESIDENT WOOLFORD: Does anyone on the floor wish to make any comments or ask any questions of Mr. Messman on the report of Committee 15?

Thank you, Mr. Messman. Your committee is to be commended for the valuable material which it has again submitted in its reports. It is a well known fact the railroads of America, and throughout much of the world, look to your committee and its recommendations not only for the basic features of bridge design, but also for the latest advancement in the art of bridge design and construction.

I am glad to see your committee give so much attention to the reviewing of its Manual material, recommending revisions where necessary or reapproving it without change to give it an up-to-date date. This is a matter to which most of our committees will have to give increased attention in the next two or three years, under the rule that committees must resubmit all Manual material for revision or reapproval at intervals of not less than 10 years. I say this because so much material throughout our Manual bears a 1953 date, the year in which the Manual, you will remember, was completely overhauled and reprinted.

Mr. Messman, your committee is now excused with the thanks of the Association.

Discussion on Clearances

[For report see pp. 501–504.]

[Vice President Woolford presiding.]

VICE PRESIDENT WOOLFORD: The next report is that of Committee 28—Clearances, of which S. M. Dahl, assistant division engineer, Milwaukee Road, at Milwaukee, is chairman. Mr. Dahl and his committee have now assembled on the podium. Will Mr. Dahl please give his report

CHAIRMAN S. M. DAHL: The report of Committee 28 is found in Bulletin 547, December 1958, beginning on page 501. Reports will be made on four of six assignments.

Assignment 1—Revision of Manual.

CHAIRMAN DAHL: Since no revisions have been proposed, there will be no report on Assignment 1.

Assignment 2—Clearances as Affected by Girders Projecting Above Top of Track Rails, Structures, Third Rail, Signal and Train Control Equipment, Collaborating with Signal and Electrical Sections, and with Mechanical and Operating-Transportation Divisions, AAR.

CHAIRMAN DAHL: Report on Assignment 2 will be presented by Subcommittee Chairman J. G. Greenlee, clearance engineer, Pennsylvania Railroad.

J. G. GREENLEE: Mr. President, members of the Association, and guests:

Your committee is reviewing clearance with respect to modern-day equipment in third-rail territory.

Submitted as information are two diagrams. Diagram 1 is for tangent track and

curves up to 7 deg, 10 min (800 ft radius). Diagram 2 is for curved track exceeding 7 deg, 10 min.

Your committee has collaborated with Committee 13, Railway Electrification, of the AAR Electrical Section and the diagrams have been made mutually acceptable to the Electrical Section and Committee 28, except that it has been recommended that the two diagrams be combined into one, which work has been progressed.

Committee 28 will recommend in its next annual report, adoption of the composite diagram, looking to Association action thereon at the 1960 convention.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Greenlee.

Assignment 3—Review Clearance Diagrams for Recommended Practice, Collaborating with AREA Committees Concerned, and the AAR Joint Committee on Clearances.

CHAIRMAN DAHL: The next assignment is No. 3. Although there is no report on this assignment, a statement of progress will be made by R. L. Williams, assistant engineer, Illinois Central Railroad, who is subcommittee chairman.

R. L. WILLIAMS: Mr. President, members, and guests:

Your committee has been moving steadily in its work on this assignment. It is with regret, however, that no recommendations can be made at this time.

Your committee has been collaborating closely with the AAR Joint Committee on Clearances. Both committees realize acutely the impact upon the industry of any changes in clearance diagrams and are, therefore, proceeding slowly and cautiously. It is expected that concrete results will be forthcoming soon, and your committee will be prepared to present a full report of its recommendations at the next Association meeting.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Williams.

Assignment 4—Compilation of the Railroad Clearance Requirements of the Various States.

CHAIRMAN DAHL: Report on Assignment 4 will be presented by Subcommittee Chairman J. F. Smith, inspector, Illinois Central Railroad.

J. F. SMITH: Mr. President, members of the Association, and guests:

Your committee submits as information a tabulation of the clearance requirements of the various states brought up to date as of November 17, 1958.

The clearance requirements of the states of Connecticut, Kansas, Maine, Montana, New Hampshire, Oklahoma, and Rhode Island are shown for the first time. Also, revisions in clearance requirements are shown for the states of Massachusetts, Pennsylvania, South Dakota, and Washington.

Your committee is now engaged in a complete reworking of the clearance chart and would appreciate any suggestions. Thank you.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Smith.

Assignment 5—Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear, and Spring Deflection, Collaborating with the Mechanical Division, AAR.

CHAIRMAN DAHL: Report on Assignment 5 will be presented by Subcommittee Chairman E. E. Mills, draftsman, Pennsylvania Railroad.

E. E. MILLS: Mr. President, members of the Association, and guests:

Unfortunately, the main part of the report of this subcommittee, together with three exhibits, were inadvertently left out of the report as it appears in the Bulletin. Mr. Howard has advised, however, that the report, in its entirety, will appear in the proceedings. [See following page].

The report this year, suggests a method of determining clearance allowances for horizontal movements of passenger cars and concludes one phase of the assignment. The report has been submitted to the Mechanical Division for collaboration, with the view of presenting it for inclusion in the Manual in 1960.

At the convention last year, you were informed that additional tests on freight equipment would be carried out in 1958 on the Lackawanna Railroad. Due to unforeseen circumstances these tests were postponed and are now scheduled for this year.

In addition to these tests, the AAR research staff, in collaboration with the Burlington Railroad, is planning tests with trailer-on-flat-car equipment, to be carried out this year. The information secured from these tests will be of considerable value in progressing the assignment, and will be the subject of a future report.

[Following is that part of the report on Assignment 5 which was inadvertently left out of Bulletin 547.]

CLEARANCE ALLOWANCES FOR HORIZONTAL MOVEMENTS OF PASSENGER CARS DUE TO LATERAL PLAY, WEAR AND SPRING DEFLECTION

The calculation of lateral clearance requirements for passenger cars on curved track involves the following factors:

1. Width of cars.
2. Overhang at ends and middle of cars due to curvature.
3. Elevation of outer rail.
4. Lateral play between wheels and rails.
5. Roll of car body, due to unequal spring deflections and play in side bearings.
6. Displacement due to swing-hanger movements and lateral play and wear in truck parts.
7. Allowances for the effect of track irregularities and dynamic behavior of equipment.

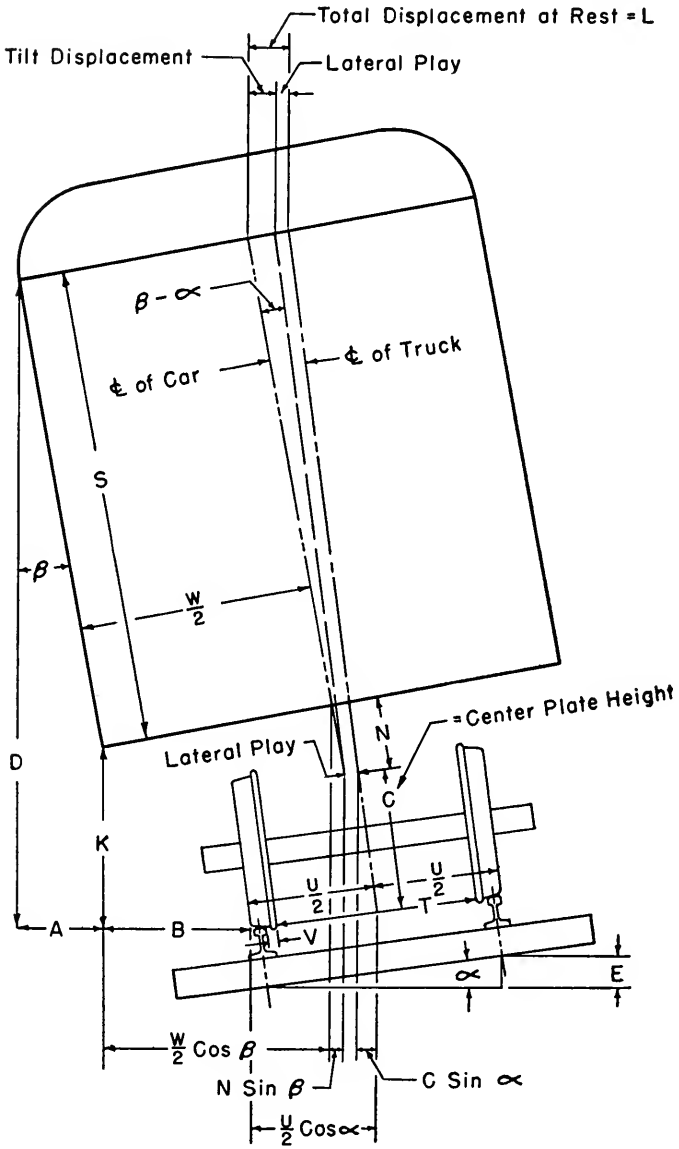
The first four factors can easily be calculated and present no problem. A method of determining allowances for factors 5, 6 and 7 is presented below.

The roll of the car body, with respect to the truck, on curved track occurs when the effect of the centrifugal force is not exactly balanced by the elevation in the track. When this condition exists, there is an "unbalanced elevation" equal to the deficiency or excess of elevation required for equilibrium. Such unbalanced elevation has a similar effect on a moving car as elevated track has on a standing car for equal values of unbalanced elevation and track elevation.

The determination of the lateral displacement of the car body due to swing-hanger movements and lateral play and wear in the truck parts, may, for all practical purposes, be combined with the lateral displacement due to tilting, and the two factors may be determined, as follows:

1. Make static tests on elevated track, preferably at 2 in, 4 in and 6 in elevation.
2. Make measurements as shown in Fig. 1 to determine value of L.
3. Plat L values, as in Fig 3, and draw line through the zero of coordinates and of average of L values and extend line into area of positive values of unbalanced elevation and displacement.

(Text continued on page 1113)



$$L = (S+N)\sin(\beta-\alpha) + (B + \tfrac{U}{2}\cos\alpha) - (\tfrac{W}{2}\cos\beta + N\sin\beta + C\sin\alpha)$$

FIG. 1 DIAGRAM SHOWING STATIC TEST MEASUREMENTS REQUIRED FOR CALCULATION OF "L"

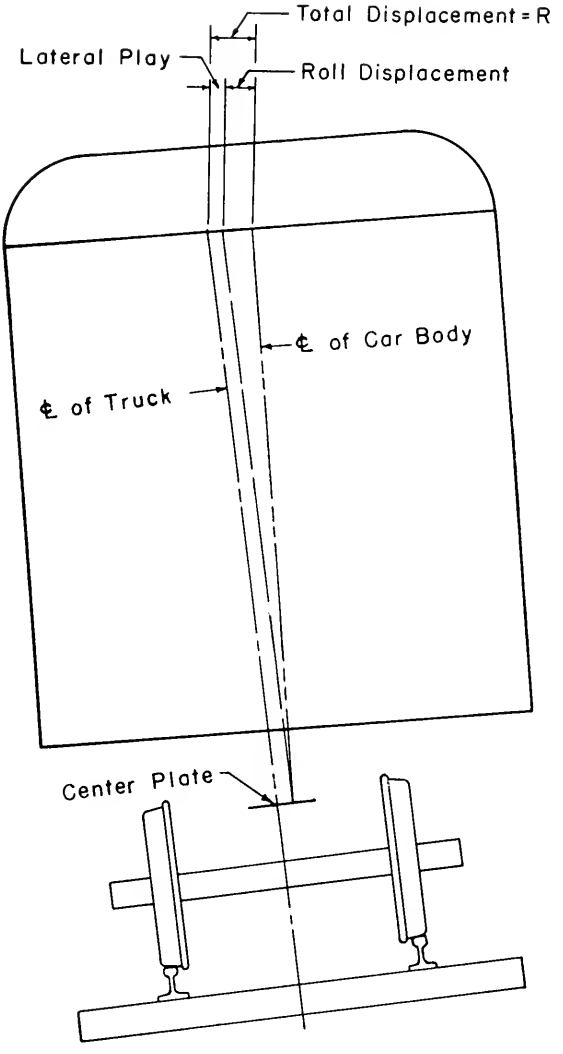


FIG. 2 DIAGRAM SHOWING DISPLACEMENT "R" OF A CAR MOVING ON A CURVE IN EXCESS OF EQUILIBRIUM SPEED

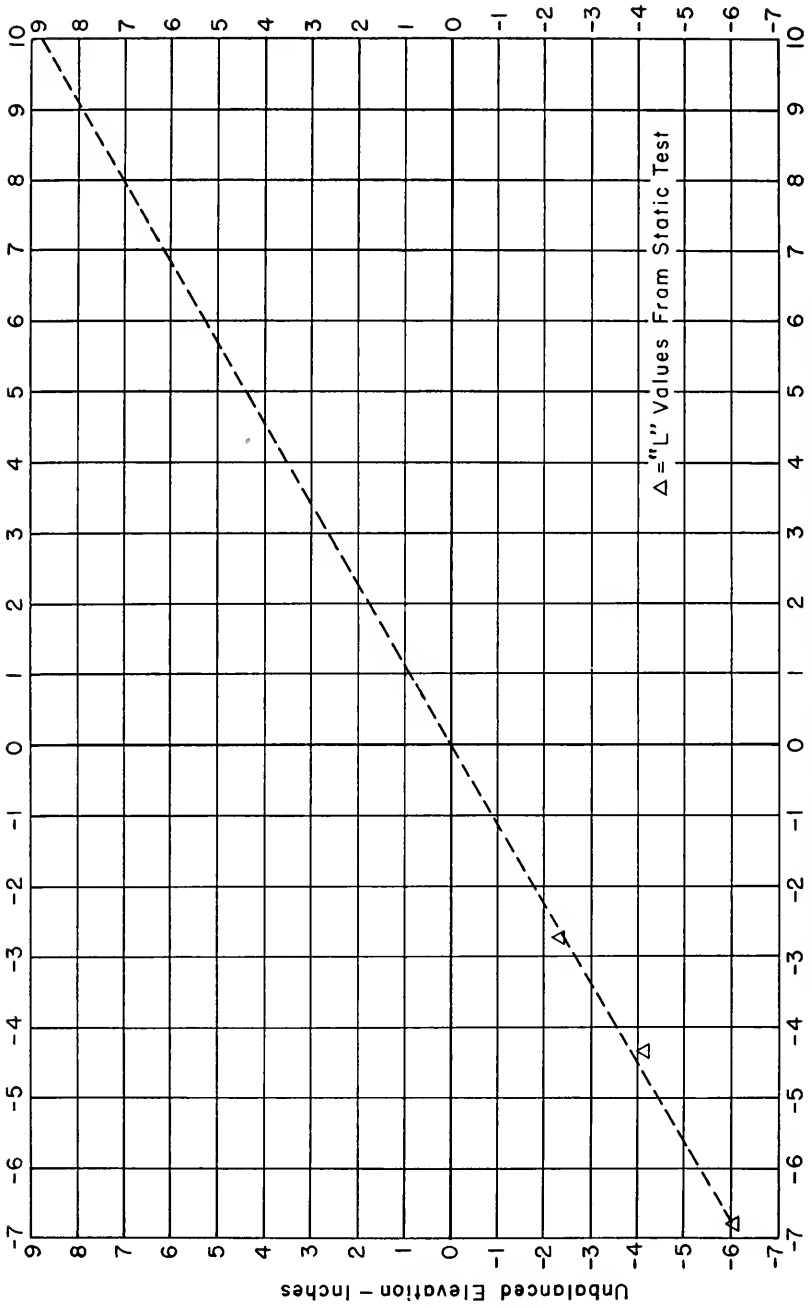


FIG. 3 DIAGRAM SHOWING RELATION BETWEEN DISPLACEMENT AND UNBALANCED ELEVATION

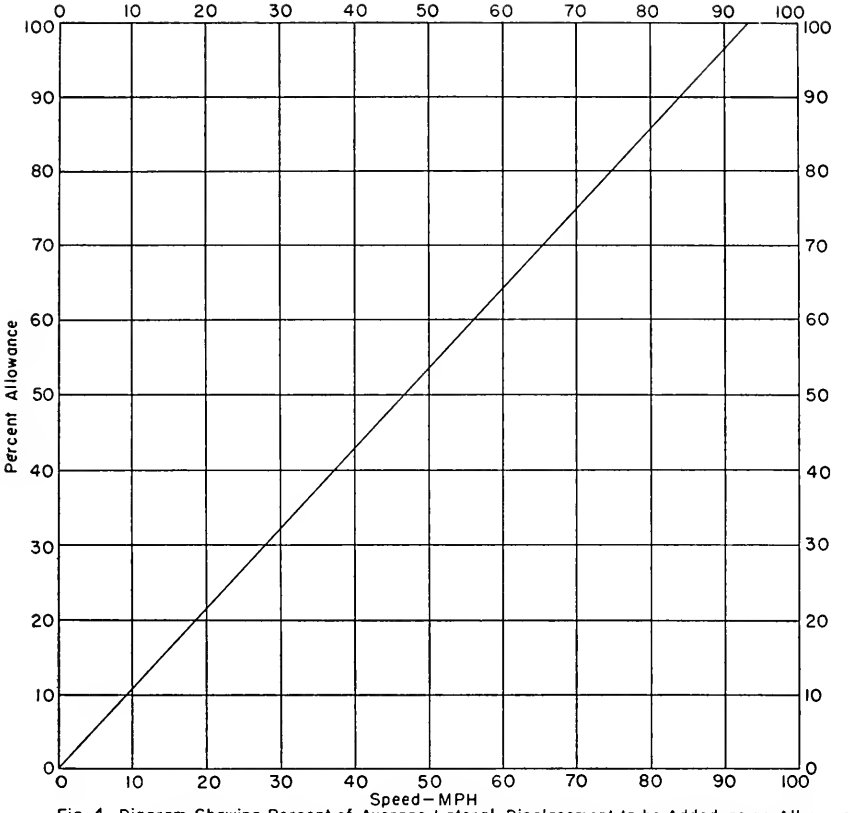


Fig. 4 - Diagram Showing Percent of Average Lateral Displacement to be Added, as an Allowance for the Effect of Track Irregularities and Dynamic Behavior of Passenger Cars.

The lateral displacement of a moving car with reference to the center line of car trucks may now be determined, as follows:

4. Calculate unbalanced elevation from formula

$$E_u = E_r - E_a$$

where

E_u = Unbalanced elevation
E_r = Elevation required for equilibrium
E_a = Actual elevation in the track

5. Determine average lateral displacement R (Fig. 2) corresponding to the unbalanced elevation, determined in step 4 from chart drawn under step 3.

The value of R may be either plus or minus, depending upon whether the speed of the car is more or less than the speed required for equilibrium.

The results obtained are only as good as the basic information, such as degree of curvature and elevation. For best results, it is recommended that actual field conditions

be determined by actual field measurement, determining curvature by string lining and elevation by cross levels. Variation of a few minutes in curvature should not be ignored.

Since track and equipment conditions are variable, to some extent, allowance must be added to the calculated average displacement to provide for track irregularities and the dynamic behavior of equipment. This allowance cannot be determined exactly. Recommended allowances, expressed as a percentage of the average displacement, for various speeds, are shown in Fig. 4 and are based upon field tests on high-speed track of eight passenger cars having various types of trucks. This allowance is to be added to the displacement as calculated above.

References: Proceedings, Vol. 56, 1955, page 125; Vol. 56, 1955, page 559; Vol. 59, 1958, page 661.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Mills.

Assignment 7—Methods of Measuring High and Wide Shipments.

CHAIRMAN DAHL: Report on Assignment 7 will be made by Subcommittee Chairman W. F. Hart, division engineer, Union Pacific Railroad. Mr. Hart.

W. F. HART: Mr. President, members of the Association, and guests:

Your committee reports progress in developing acceptable measuring devices, fixed as well as portable, recognizing the fact that with the increased number of high and wide loads it has been necessary to measure these loads many times, generally at plant sites. Initially, we have developed drawings of a fixed device for installation at terminals and interchange points. This device will afford a method of measuring these loads at the original terminal or interchange with a view that such loads can move through interchange points without the necessity of repeated re-measurements.

This will expedite movement of these loads and thus avoid complaints due to delays in handling.

The preliminary drawings are being reviewed, and it is contemplated that they will be included our 1959 report.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Hart. Your report will be considered as information.

CHAIRMAN DAHL: Mr. President, this concludes the report of Committee 28.

VICE PRESIDENT WOOLFORD: The Association thanks you, Mr. Dahl, for your efficient handling of this report. The committee is working on a number of very important assignments. It is evident that in connection with most of them it is necessary that you collaborate closely with the Mechanical Division, the AAR Joint Committee on Clearances, the Joint Committee on Relation Between Track and Equipment, and of course, the AAR research staff.

Modern train operation, new types of equipment, high and wide loads, piggy-back operations, and other factors are all presenting new problems today, and we are looking to your committee for the answers.

Your committee is now excused with the thanks of the Association.

Discussion on Waterproofing

[For report see pp. 469–471]

[Vice president Woolford presiding.]

VICE PRESIDENT WOOLFORD: Our next committee to report this afternoon is Committee 29—Waterproofing. The chairman of this committee is E. A. Johnson, engineer

of bridges, Illinois Central Railroad, Chicago. Will you please give your report, Mr. Johnson.

CHAIRMAN E. A. JOHNSON: Mr. Chairman, members, and guests of the Association:

The report of Committee 29—Waterproofing, is printed in the December 1958 Bulletin 547.

Assignment 1—Revision of Manual.

CHAIRMAN JOHNSON: The report on Assignment 1 will be presented by Subcommittee Chairman R. J. Brueske, assistant division engineer, Chicago, Milwaukee, St. Paul, and Pacific Railroad.

R. J. BRUESKE: Mr. President, members, and guests of the Association:

Your committee is now reviewing our specifications for inconsistencies and grammatical errors. We expect to complete this review during 1959, and next year will recommend the adoption of these corrections along with two revisions to our membrane waterproofing specifications.

This report is presented as information.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Brueske. Your report will be so accepted.

Assignment 2—Waterproofing Materials and Their Application to Railway Structures, Collaborating with Committees 6, 8, and 15.

CHAIRMAN JOHNSON: The report on Assignment 2 will be presented by Subcommittee Chairman E. T. Franzen, engineer of bridges, Chicago, Rock Island & Pacific Railroad.

E. T. FRANZEN: Mr. Chairman, members of the Association, and guests:

Those of you who have had occasion to use the specifications of this committee will be interested to know that the committee, at its last meeting, formally approved rewriting Part 2—Waterproofing Membranes, to modernize these specifications. Wherever applicable ASTM specifications will be incorporated for materials and tests.

We hope to overcome past difficulties in obtaining materials to meet the requirements of our specifications. The results of the basic research projects conducted at Purdue University for several years will guide us in rewriting the specifications. We will also incorporate the results of tests presently being conducted by the AAR research staff in Chicago wherein they are determining the effects of various bituminous materials, and the number of plies, on the waterproofing quality of the membrane. We have requested funds for research at Purdue University on asphalt plank and mastic, and hope to have results of this investigation available to guide us in rewriting the portion of the specifications pertaining to these materials.

This is a progress report.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Franzen. Your report will be so received.

Assignment 3—Coatings for Dampproofing Railway Structures, Collaborating with Committees 6 and 8.

CHAIRMAN JOHNSON: The report on Assignment 3 will be presented by W. P. Hendrix, engineer of bridges and buildings, Pennsylvania Railroad, chairman of the subcommittee.

W. P. HENDRIX: Mr. Chairman, members, and guests:

This report is submitted as information.

The testing of water-repellant coating materials was continued at Purdue University. The degree of wetting of these materials by water, as measured by determinations of the wetting angle, is being used as a crtierion of waterproofness. Measurements have been made on 14 bituminous emulsion films in both a dry state and after immersion in water. Such immersion materially reduces the ability of the coating to withstand the entrance of water into imperfections.

These coatings, as well as several silicone waterproofing materials, are being weathered in an accelerated test to determine the degree to which their water repellancy is affected by such weathering.

The diffusion of water through intact, free films of the bituminous materials is being measured in an effort better to understand this process.

A report was submitted on the durability of a large number of bituminous coatings after outdoor exposure for five years. Very large differences in durability were found for the various materials.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Hendrix. Your report will received as information.

CHAIRMAN JOHNSON: Mr. Franzen in his report called attention to rewriting our specifications for waterproofing membranes. This is also being done for easier reading and understanding, which is now most important because of the many states and new contractors which are using these specifications in connection with new grade separation projects.

Your committee is represented on ASTM Committee D8, Membrane Waterproofing and Built-Up Roofing.

Progress has been reported on our various assignments, and the committee welcomes suggestions from members of the Association regarding the work of this committee.

Mr. Chairman, this concludes the report of Committee 29.

VICE PRESIDENT WOOLFORD: Thank you, Mr. Johnson. Your committee necessarily has had a very limited number of assignments, but they are very important ones if we are going to find the answers to developing the most effective waterproofing and dampproofing materials and keep our specifications abreast of the best practices. We hope your committee will keep after these problems until they are solved satisfactorily.

I know, Mr. Johnson, your committee is somewhat short of the number allowed on the committee. I wish to take this opportunity to request the various carriers represented in our association to get a few more members on your committee, which I think would be beneficial.

Mr. Johnson, your committee is now excused with the thanks of the Association. [Applause]

[Vice President E. J. Brown assumed the chair.]

Discussion on Wood Preservation

[For report see pp. 341–377.]

[Vice President Brown presiding.]

VICE PRESIDENT BROWN: We will next hear from Committee 17—Wood Preservation. P. D. Brentlinger, forester, Pennsylvania Railroad, is chairman. Mr. Brentlinger and his committee is all here I see. Will you present your report, please.

CHAIRMAN P. D. BRENTLINGER: Mr. President, members, and guests of the Association:

Committee 17 reports on several of its assignments this year. Before presenting our

reports, we would like to report the death of three members—Martin Jaeger, A. L. Simpson, and most recently, on December 20, 1958, Walter Fulweiler.

Memoirs for Mr. Jaeger and Mr. Simpson, were published with our report in Bulletin 547, and a suitable memoir will be prepared for Mr. Fulweiler to be printed in the Proceedings.

MEMOIR

Walter Herbert Fulweiler

Walter Herbert Fulweiler, consulting engineer and a member of the American Railway Engineering Association for 34 years, died on December 20, 1958, in Paoli, Pa., after an extended illness. He is survived by his wife, the former Lydia Baird; three sons, John H., Spencer B. and Thomas B.; a daughter, Mrs. H. R. Pyne, Jr., and a brother.

Mr. Fulweiler was born in Philadelphia, Pa., on January 3, 1880. He attended public schools in Philadelphia and graduated from the University of Pennsylvania with a B.S. degree in chemistry in 1901.

After graduation Mr. Fulweiler was engaged as chemical engineer by the United Gas Improvement Co. In 1930 he became associated with the Philadelphia Gas Works Co. From 1935 until his death he was a consulting engineer with offices in Philadelphia. This work gained Mr. Fulweiler wide affiliations and contacts.

Mr. Fulweiler joined the AREA in 1924 and had been a member of Committee 17—Wood Preservation, since 1945. He made major contributions to the art of wood preservation in the development of specifications for creosote, creosote-coal tar and specifications for analysis of these materials. His outstanding work in this field contributed to fundamental wood preservation policies of railroads.

Mr. Fulweiler was a past president of the American Society for Testing Materials, 1925–1926, and was active in the American Wood-Preservers' Association. Other society affiliations included the American Chemical Society, American Society of Mechanical Engineers, Society of Chemical Industries, Physical Society and Optical Society. He was also affiliated with the International Association for Testing Materials, serving as vice president in 1934.

Mr. Fulweiler achieved a number of distinguished awards, including the Grasselli Medal in 1922 and the Beal Medal of the American Gas Association in 1934. He was made an honorary member of the American Society for Testing Materials in 1946.

Aside from his business duties Mr. Fulweiler enjoyed his hobby of astronomy and spent many happy summer hours with his family at their summer home in Bar Harbor, Me. He was a member of the Episcopal Church.

Walter Fulweiler has left behind a wealth of achievement and personal service that provide a monument to his fruitful life and career.

Assignment 2—Specifications for Wood Preservatives.

CHAIRMAN BRENTLINGER: Under Specifications for Wood Preservatives, Assignment 2, a progress report will be presented by Walter Barger of the Santa Fe.

W. W. BARGER: Mr. Chairman, gentlemen:

The report on this assignment is made up of five parts and is submitted as information only.

Part 1. Keep up to date current specifications for preservatives:

We have no changes this year but one is in prospect for next year.

Part 2. Review and report on new preservatives.

Your committee has been studying osmosalts as a new preservative. Definite decision on this subject is expected next year.

Part 3. Review method of sampling creosote in tank cars.

This subject has been studied extensively and we are in position to make a full report next year.

Part 4. Study advisability of establishing the flash point of creosote.

Your committee is of the opinion that the establishment of the flash point of creosote is not necessary at this time and recommends that this part of the assignment be dropped.

Part 5. Review "comments" after preservative specifications; report on need for comments with view toward continuance, deletion or change in title.

This subject has been studied extensively and we are in position to make full report next year.

VICE PRESIDENT BROWN: Thank you, Mr. Barger.

Assignment 3—Specifications for Petroleum as a Carrier for Standard Wood Preservatives.

CHAIRMAN BRENTLINGER: Report on Assignment 3 will be made by T. H. Patrick, supervisor of tie bureau, Milwaukee Road.

T. H. PATRICK: Members of the Association and visitors:

There are two parts to this assignment this year. The first part is to review and bring up to date our specification for petroleum for blending with creosote. We have had considerable discussion on this, and we recommend that there be no change in this specification made at this time. Under Part 2, we prepared a specification for petroleum for blending with pentachlorophenol, which you will find on pages 344 and 345 of Bulletin 547. I wish to call your attention to two errors in this report. At the bottom of page 344, at the end of the last sentence there should be added "AWPA Method A5–58." At the top of page 345 the first sentence says, "Test to determine the foregoing requirements shall be made in accordance with the ASTM method currently in effect." Reference to "ASTM" should be deleted because there are two methods used in this specification.

Pentachlorophenol, as you know, is receiving considerable use, and some standard was needed for the petroleum solvent. Due to the many changes that are taking place in the production of petroleum, we are prepared to revise the specification to meet the changes as time passes on.

I move that the Specification for Petroleum Solvent for Pentachlorophenol printed on pages 344 and 345 of Bulletin 547, with the corrections mentioned above, be adopted and published in the Manual.

[The motion was duly seconded, was pute a vote, and carried.]

Assignment 4—Specifications for Preservative Treatment of Forest Products, Including Laminated Timbers, Collaborating with Committees 6 and 7.

CHAIRMAN BRENTLINGER: The report on Assignment 4 will be presented by L. C. Collister, manager, Tie and Timber Treating Department, Santa Fe.

L. C. COLLISTER: Mr. Chairman, members, and guests:

In reviewing the species classified as Td, it will be noted that the heart sections of some of these trees are included in group Ud, that is, those that can be used untreated, namely, the catalpas, chestnut, sassafras, and red mulberry. The other species—ashes,

beech, birches, cherries, elms, hackberries, hickories, hard maples, soft maples, poplars, sycamores, and white walnut—treat pretty much alike and can be easily loaded with preservative. Therefore, it is recommended that the Td species, as listed, be treated to 9 lb retention as indicated in the table accompanying our report in Bulletin 547.

This is a progress report presented as information.

VICE PRESIDENT BROWN: Thank you, Mr. Collister.

Assignment 7—Service Test Records of Treated Wood.

CHAIRMAN BRENTLINGER: The report on Assignment 7 will be presented by Subcommittee Chairman R. P. Hughes of the Santa Fe.

R. P. HUGHES: Mr. President, gentlemen of the Association:

Your committee submits four reports on service test records of treated fence posts, as follows:

1. Report on 1958 inspection of Atchison, Topeka & Santa Fe Railway's treated fence post test at Cleveland, Tex.

2. Report of 1955 inspection of treated fence posts in right-of-way fence of Missouri–Kansas–Texas Railroad between South Canadian River and Canadian, Okla.

3. Report of 1957 inspection of treated fence posts in fence line on Lars Friesth farm near Humboldt, Iowa, by Wood Preserving Division, International Paper Company.

4. Comparison of Wood Preservatives in Mississippi post study, 1958 Progress Report, by J. Oscar Blew, Jr., technologist, and John W. Kulp, technologist, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.

This report is submitted as information.

VICE PRESIDENT BROWN: Thank you, sir.

Assignment 8—Destruction by Marine Organisms: Methods of Prevention.

CHAIRMAN BRENTLINGER: Next comes the report on Assignment 8, but since Subcommittee Chairman A. P. Richards couldn't be here this afternoon, his report is presented as printed in the Bulletin.

Assignment 9—Destruction by Termites: Methods of Prevention, Collaborating with Committees 6 and 7.

CHAIRMAN BRENTLINGER: Assignment 9 is Destruction by Termites, Methods of Prevention, Collaborating with Committees 6 and 7. I call your attention to the fact that the termite control investigation being carried on under this assignment is summarized in Bulletin 545. Subcommittee Chairman F. J. Fudge, timber engineer, New York Central, will make a report on the progress of this research.

F. J. FUDGE: The first inspection of the termite control test plot at the University of Florida was made January 8, 1959, by Dr. Huffman, L. R. Morgan and myself. The test was 14 months old at time of inspection.

Results of this inspection will be presented in next year's report of Committee 17; however, a brief summary of the inspection is as follows:

Slight and moderate termite attack was found in some stakes having a light retention of chromated zinc chloride and celcure preservatives. Localized to slight decay was found in some stakes having a light retention of tanalith, celcure, boliden salt and green salt preservatives.

The untreated control stakes had various grades of decay and termite attack. One oak stake failed from decay at the ground line.

The logarithmic indexes of decay and termite damage for the untreated controls (10 specimens each species) after 14 months exposure are as follows:

Species	Decay Index*	Termite Index*
Southern yellow pine (sapwood)	71	85
Red oak	80	89
Douglas fir (heartwood)	98	81

* 100%, indication of no damage.

Where termites were found, they were still active.

The test plot has not been in service long enough to make any conclusions.

During 1959, the test plot will be enlarged to include stakes treated with creosote coal-tar and creosote-petroleum solutions.

CHAIRMAN BRENTLINGER: Mr. Chairman, this concludes the reports of the subcommittees on their assignments. We would like to say that we made note of President Meyer's remarks this morning that he believed that perhaps standardization in the treatment of cross ties might reduce the cost. We would like to have you know that the committee is always on the lookout for new and better ways, and probably standardized ways of treating forest products.

VICE PRESIDENT BROWN: Thank you, Mr. Brentlinger.

In view of the vast amounts of timber used by the American railroads in track and structures, your committee has had a tremendous responsibility to keep the specifications of the Association up to date with respect to wood preservatives and methods of wood preservation, and in developing new specifications as may be required. Accordingly, we are glad to note the continued attention you give to the matter of specifications each year.

Thank you and the members of your committee for a very effective year. Your committee is now excused with the thanks of the Association. [Applause]

Discussion on Buildings

[For report see pp. 315–330.]

VICE PRESIDENT BROWN: Our next committee to make a report is Committee 6—Buildings, of which S. G. Urban, architect, Texas & Pacific Railway, Dallas, Tex., is chairman—Mr. Urban having been advanced from vice chairman to chairman of the committee last fall to fill the vacancy created by the death of Dwight E. Perrine, assistant chief engineer, Chicago & Western Indiana Railroad. Mr. Urban, will you and the members of your committee please come to the platform and present your report.

CHAIRMAN S. G. URBAN: Mr. Vice President, members, and guests:

Committee 6—Buildings, respectfully submits its report as printed in Bulletin 546, November 1958, on pages 315 through 330. Interesting and useful information is included on three committee assignments. Our remaining assignments are under study with a good amount of material gathered for future informative reports.

Following an illness of six months, death on September 21, 1958, took Dwight E. Perrine, chairman of this committee. Sorrow for the passing of this valued member of the Association has been expressed by his many friends and associates. A memoir for him was published with the report of this committee.

Assignment 2—Specifications for Railway Buildings.

CHAIRMAN URBAN: The report on Assignment 2 will be made by the subcommittee chairman, H. T. Seal, engineer of buildings, Chesapeake & Ohio Railway, Richmond, Va.

H. T. SEAL: Mr. President, members of the Association, and guests:

Your committee is submitting for adoption and publication in the Manual, specifications for application of asphalt shingles.

Mr. President, I move that these specifications as presented on page 317 in Bulletin 546 be included in the Manual.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 6—Buildings and Structures for Hump Classification Yards with Retarders, Collaborating with Committee 14.

CHAIRMAN URBAN: The report on Assignment 6 will be presented by Subcommittee Chairman A. B. Ryan, chief architectural draftsman, Louisville & Nashville Railroad, Louisville, Ky.

A. B. RYAN: Mr. Chairman, members, and guests: This report is for information only.

The need for information concerning the requirements of the various types of buildings necessary for the operation of a modern "push-button" hump classification yard is apparent. The members of this committee, realizing this need, have approached this study with the purpose of making available to the architect or engineer of any railroad the basic minimum architectural requirements for these buildings.

Every retarder yard has its own particular requirements which are impossible to cover in report such as this. However, all of these modern yards have certain essential requirements for buildings. For instance, every retarder yard must have a retarder tower, one or two yard offices and checker buildings. These are the absolute essentials.

Confining its study to retarder yards with 50 to 60 classification tracks, your Committee presents in its report, in detail, the ideal requirements for the four most essential types of buildings: retarder tower, main yard office at hump, yard office between classification and departure yards (referred to in this report as bowl yard office,) and car inspector booth ahead of hump. It also presents brief information on checker buildings and tool and storage buildings.

The committee hopes the information presented will be an aid to the railroad architects and engineers facing for the first time the necessity of designing buildings for hump classification yards with retarders.

VICE PRESIDENT BROWN: Thank you, Mr. Ryan.

Assignment 8—Infra-Red Ray Heating, Collaborating with Electrical Section, AAR.

CHAIRMAN URBAN: A progress report on Assignment 8 will be made by the subcommittee chairman, J. W. Gwyn, assistant engineer, Missouri Pacific Railroad, St. Louis, Mo. Mr. Gwyn will also introduce the speaker for the special feature offered by this committee.

J. W. GWYN: Mr. President, gentlemen:

Your subcommittee assigned to the investigation of infra-red ray heating as applied to railway buildings has been collaborating during the past year with the Electrical Section of the AAR. We are submitting at this time a progress report as information.

Much of the work in progressing this joint assignment has been done by Leonard R. Morgan, assistant research engineer structures, AAR, who will now present an adaptation of our preliminary report. Mr. Morgan.

Practical Application of Infra-Red Ray Heating to Railway Buildings

By L. R. Morgan
Assistant Research Engineer Structures, AAR

Mr. President, Mr. Chairman, members and guests:

I believe that consideration of this subject should be prefaced by a brief explanation of the fundamental characteristics of the electromagnetic spectrum and the relative position of the infra-red ray band.

As shown on Slide 1 the spectrum covers a wide range of wave lengths ranging from those of the gamma ray of nuclear processes to the electronic waves of the order used in broadcast work. The term "infra-red" is used to denote the position of it in relation to the red color of the visible light band, being beyond the longest visible ray. The terms "near infra-red" and "far infra-red" are common to a discussion of this subject in regard to the visible light band; the near infra-red comes from that part nearest the visible light while far infra-red comes from that farthest from such light. It is thus seen that the conventional electric infra-red or heat bulb is of the near-infra-red order, with part of the energy in the form of light.

Your attention is called to the relative position of the ultra violet ray band which shows that such rays are on the opposite side of the visible light band, thus insuring that no ultra violet rays can be included in infra-red ray heating. Infra-red rays being beyond the visible light band can, of course, produce no glare.

Infra-red rays are the source of all the heat derived from the sun and travel from there at a speed of 186,000 miles per second, reaching the earth in about 8 min. Such rays do not heat the space through which they pass because they are in themselves not heat, but convert to heat when they strike an object which absorbs the rays. These rays can be focused and reflected, the latter property being used in the design of heaters. The infra-red rays are generated on the surface of the sun by the combustion of gases at an estimated temperature of 6,000 deg C or 11,000 deg F. In a similar manner the infra-red rays can be generated by heating a surface by means of burning gas—natural, mixed or propane. The wave length of the infra-red radiation emitted by a hot body depends on the temperature of its surface (hotter surfaces giving off shorter waves), while the quantity of heat radiated increases as the fourth power of the absolute temperature. For example, a surface at 1600 deg F (2060 deg absolute) emits 96 times as much infra-red as a surface at 200 deg F (660 deg absolute) of the same area.

One of the principal types of infra-red ray heaters as manufactured in this country is shown on Slide 2. This heater operates at the above-mentioned 1600 deg F temperature. Another view of a similar heater, but of one unit size, is shown on Slide 3. Slide 4 shows the basic size of the ceramic mat used in this type of heater. It is 2½ in long, 1¾ in wide and ⅜ in thick. It is perforated with 896 holes and permits the development of the 1600 deg temperature at its face while only developing 400 deg at the rear, thereby insuring against flash back into the body of the burner. Slide 5 shows a typical overhead installation of this type of burner; one railroad inspected had a similar installation with the heater about 41 ft high so as to clear a traveling crane, this height having no adverse effect on the operation of the heater since the intervening air is not heated by the passage of the infra-red ray.

A newer development has produced parabolic reflectors which may be mounted on the inner surface of outer walls with good results. Individual venting of this type of

infra-red ray heater is not required since adequate powered or gravity exhaust vents, located in the center of the building, will prove satisfactory. Before the capacity of any ventilation system is determined all applicable codes and insurance requirements should be considered. The air required for complete combustion of gas is approximately 10 cu ft per hr for every 1000 Btu per hr. This amount is the additional quantity of air required because of the installation of this type of heater.

Condensation is a common occurrence on the inside surface of industrial and commercial buildings, and the use of infra-red ray heating not individually vented does, of course, release the products of combustion, including water vapor, in the building enclosure. Condensation can be most economically controlled by insulating cold surfaces to keep the inside surface above the dew point of inside air and by cooling and diluting the products of combustion so as to maintain the relative humidity as low as possible.

The use of this first-mentioned type of infra-red heat is permissible in semi-hazardous areas, such as in garages and diesel shops, provided that a stainless steel screen is mounted so as to cover the entire open end of the heater. When heaters are so equipped the installation meets the requirements for semi-hazardous areas as outlined by the Underwriters' Laboratories.

The design of this type of infra-red ray heating system requires the use of the conventional method of determining the heat loss for the building. The results of such calculations are then subject to the influence of the following factors, largely peculiar to infra-red ray heating:

1. Placement of the heaters.
2. Consideration of the fact that the heating will be from floor up rather than roof down; resulting in comfortable temperatures in the immediate area where work is to be done.
3. Decrease in movement of air.

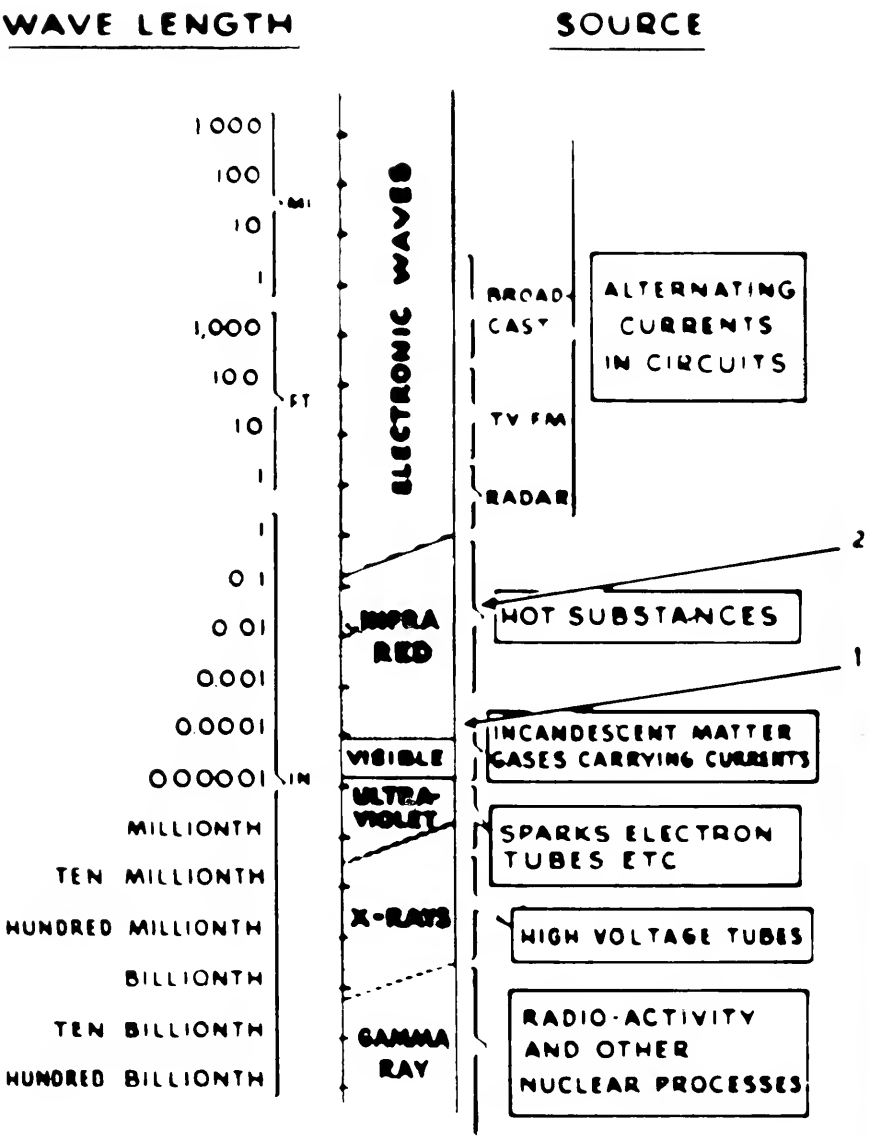
Records of several typical installations ranging in size from 900 to 45,000 sq ft indicate that savings in fuel costs may average about 30 percent, with some instances reporting up to 50 percent saving. The installation costs, including both labor and material, of this brand of infra-red ray heating may in some instances run up to 30 percent in excess of conventional installations except where boiler plant is required; in that case the infra-red ray heater installation cost may be even less than that of the conventional system.

I am sure that you all realize that the limited time available does not permit detailed consideration of the design of heating systems; however, I am equally sure that you will encounter no difficulties in familiarizing yourself with the additional steps incidental to the use of infra-red ray heating.

In some installations the pilot flame may be exposed to possible drafts or gusts of wind, in which case, after such exposures have been minimized, arrangements can be made so as to insure automatic relighting of the pilot in event of extinguishment.

Another trade brand of infra-red ray heater is basically similar to the first described; in fact, its manufacture is permitted under the same license. This brand is shown on Slides 6, 7 and 8. There are certain features of this brand which should be considered in any study of the over-all picture, among which is the claim that they are more efficient due to a smaller "dark" area on the face of the ceramic mat. This brand has not attained the wide distribution enjoyed by the first-described brand. Present information is to the effect that it has only limited approval by the Underwriters for use in hazardous areas; this fact is important and should be thoroughly investigated for any specific case.

(Text continued on page 1131)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VISIBLE
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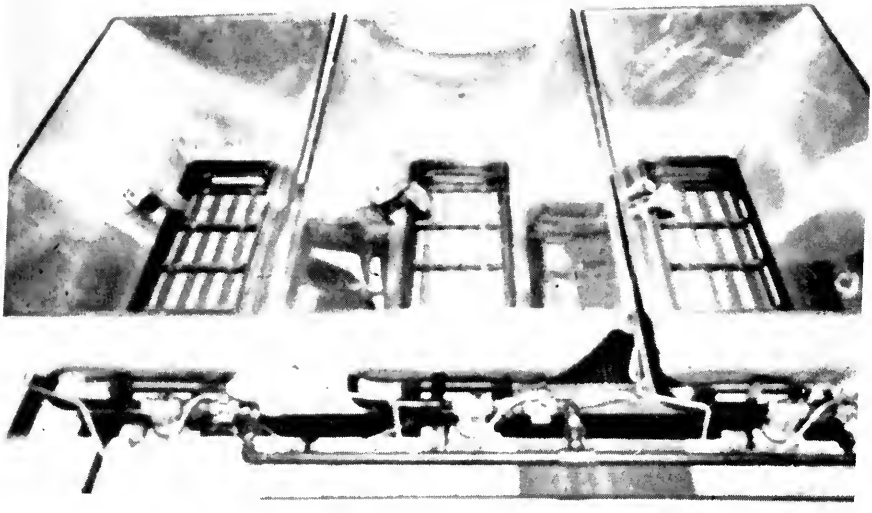
X-RAYS
GAMMA RAY
BROAD CAST
TV FM
RADAR
ALTERNATING CURRENTS IN CIRCUITS
2
HOT SUBSTANCES
1
INCANDESCENT MATTER GASES CARRYING CURRENTS
SPARKS ELECTRON TUBES ETC
HIGH VOLTAGE TUBES
RADIO-ACTIVITY AND OTHER NUCLEAR PROCESSES

Slide 1.



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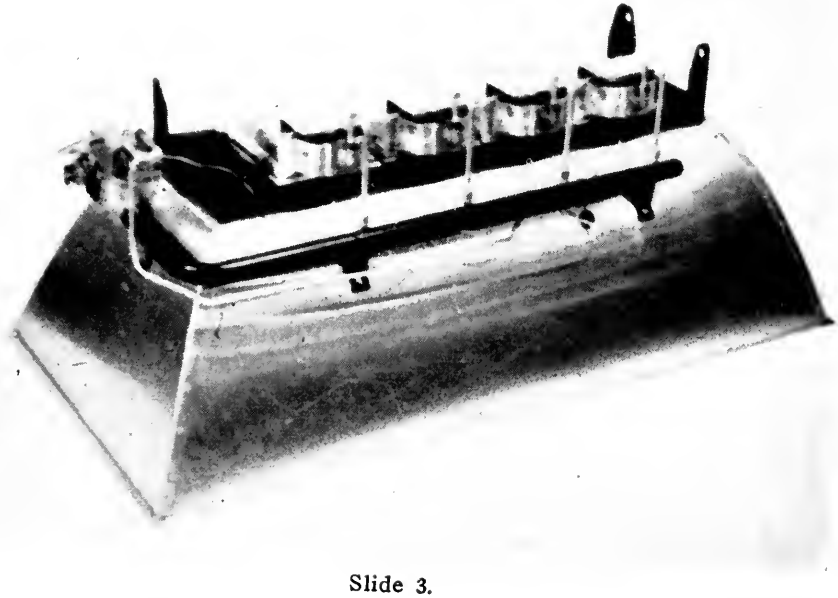

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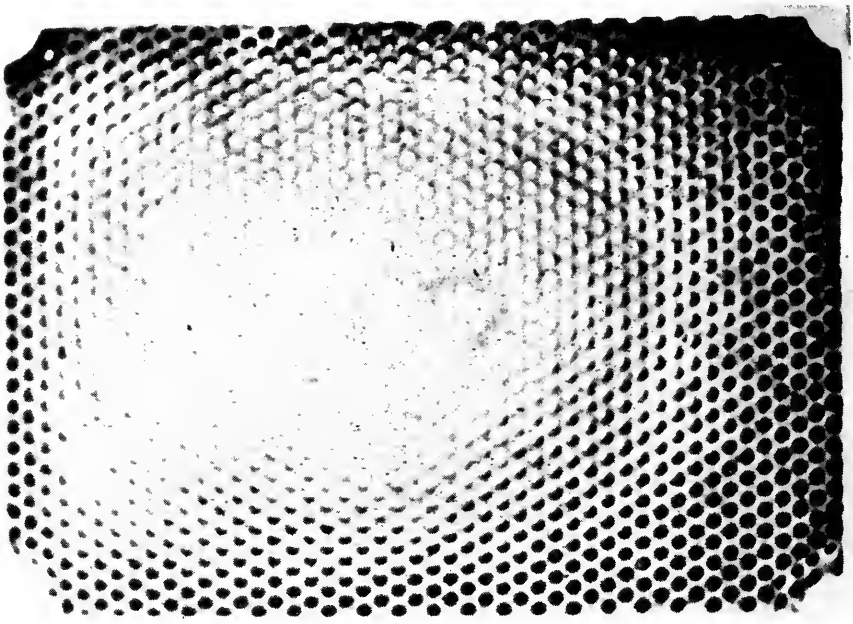

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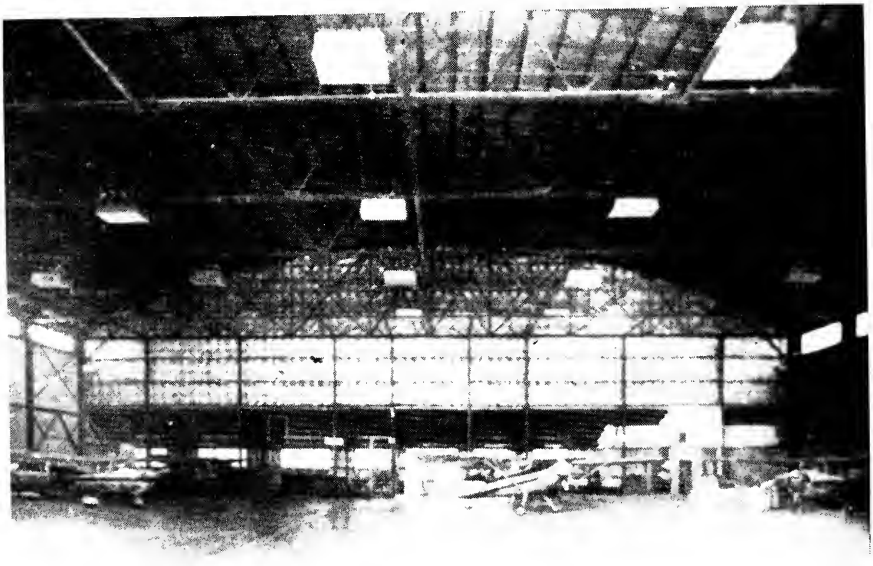

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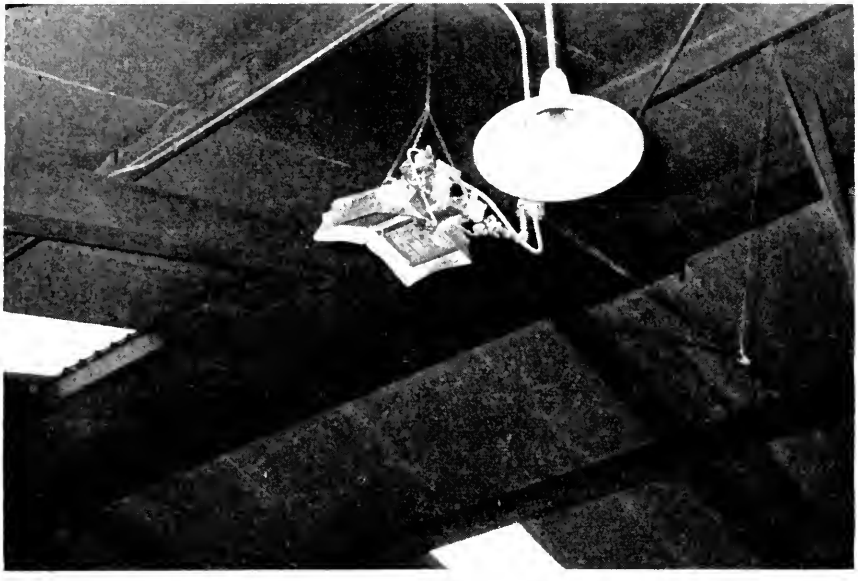

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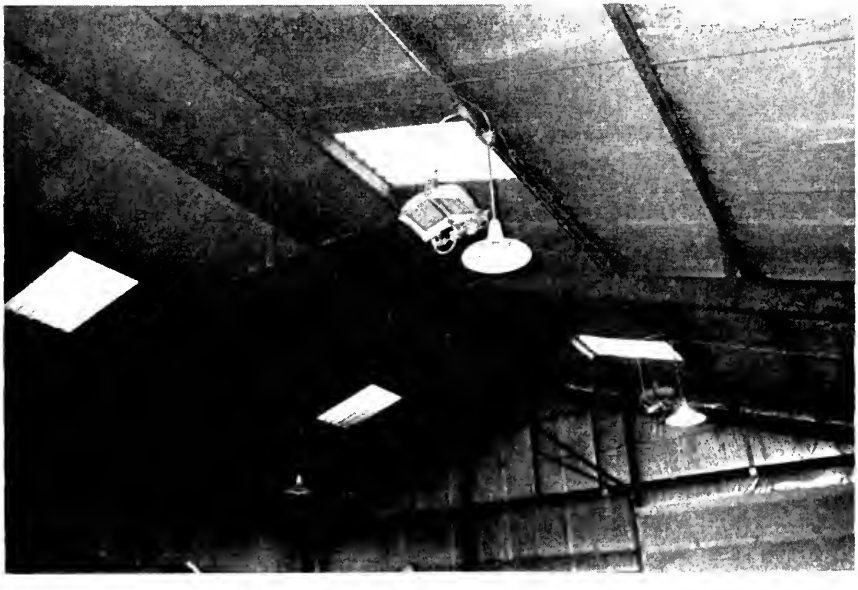

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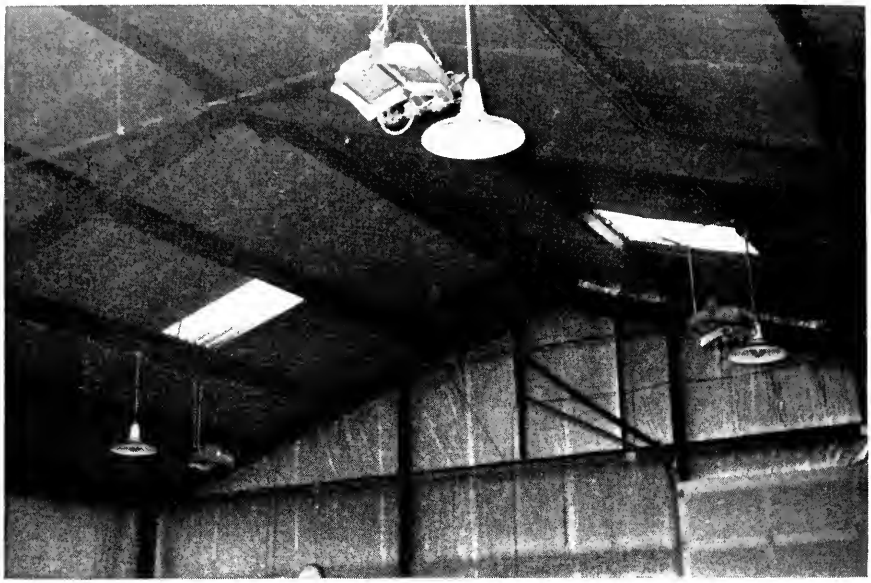

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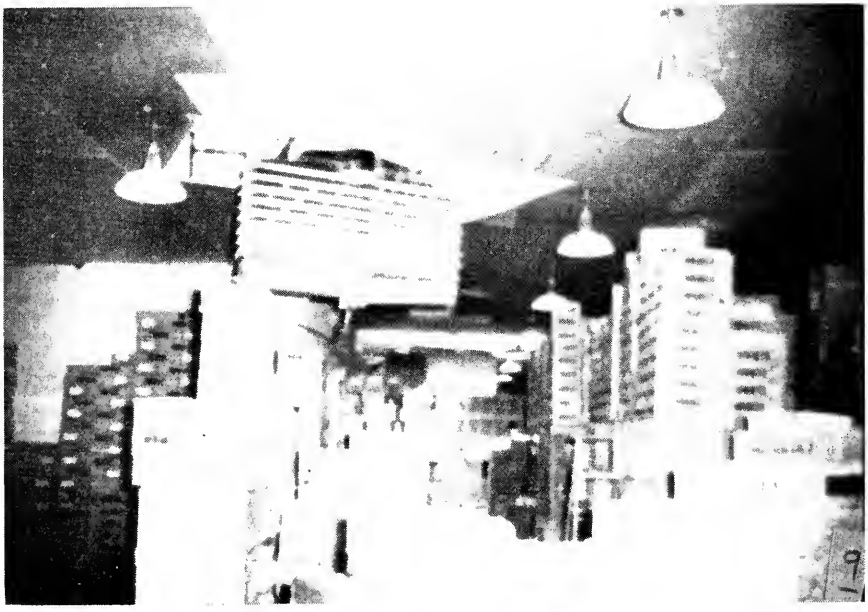
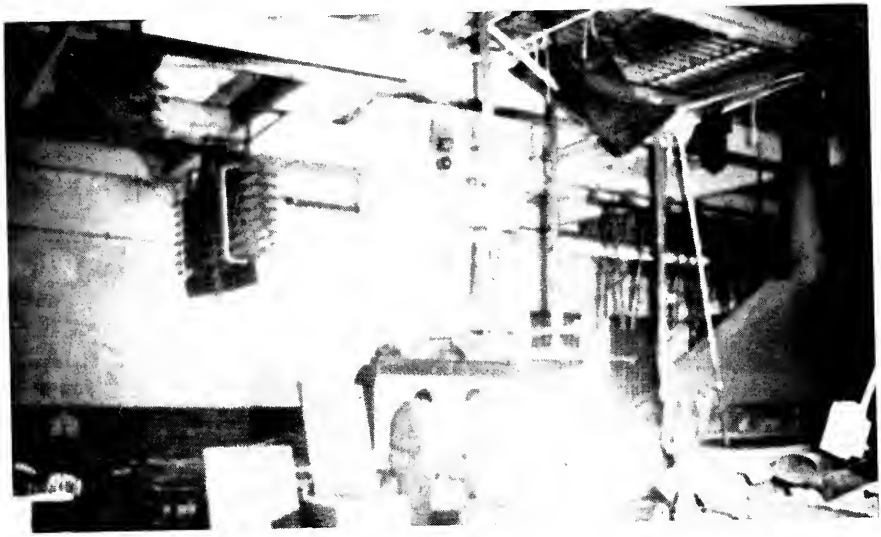


Slide 9.

Slide 10.



Slide 11.

Slide 12.

There is a third trade brand of gas infra-red ray heater of quite different construction, which is shown on Slide 9. This heater is of also the overheat type with standard gas burner with primary and secondary air intakes. The combustion chamber is built of heavy special aluminum-bearing alloy steel protected by a high-temperature vitreous enamel. This enamel is highly heat resistant and is intended to provide maximum durability against the corrosive products frequently found in commercial gases. The panel-type heating chamber is scientifically designed with tortuous gas passages to insure full utilization of the fuel, thereby promoting high efficiency.

This type of heater requires individual venting for each unit; however, such being the case there are no additional problems involving ventilation and condensation. The same method of design of heating system is recommended except that the manufacturer suggests that heat loss through the walls above a 15-ft level be neglected in arriving at total heat required. There are many installations of this type of heater and its consideration seems warranted, particularly in relatively small structures or rooms. It seems adapted to general office heating and possibly for light manufacturing work. Slides 10 and 11 show other installations of this trade brand of heater.

All of the three brands of infra-red ray heating so far considered are adaptable to spot heating of points in an otherwise unheated building. Likewise, they may be arranged so as to heat open loading platforms and similar outdoor areas, the outdoor use being principally confined to the first two types discussed.

Another type of infra-red ray heating is that generated by electric heating of surfaces which, in turn, generate infra-red rays. There are several trade brands of such heaters. Two railroad installations, each located in an open-sided car repair shop, consist of racks placed alongside the repair track; each rack had nine 2,500 w heater tubes. The rack is 108 in long by 32 in wide, and the tubes occupy most of the area of the rack. The racks, in groups of two, are arranged in staggered position, first one on one side and then one on the other side of the track, with 5 ft longitudinal spacing between the racks. In this position two racks adequately heat a track length of about 28 ft. The cost of such heat, except in areas served by TVA or similar means, is generally excessive except for certain cases where the cost would be more than offset by the particular advantages gained from such method of heating. Slide 12 illustrates a typical electric infra-red ray heater.

The foregoing presentation has dealt with some of the fundamentals of infra-red ray heating and the slides have shown the location of heaters in buildings not unlike those freequently found on railroads. Interested members are referred to the report of this committee earlier presented by Mr. Gwyn, since it contains an inspection report of several installations involving the use of the various types of infra-red heaters herein described. The expanding network of gas distribution mains continues to widen the availability of natural gas at costs which will permit the economical operation of infra-red ray heaters in increasing numbers.

In closing may I thank you for your careful attention and immediately following the presentation I will be available to answer any inquiries and to give references to factory representatives who are also immediately available. [Applause]

Chairman Urban: Thank you, Mr. Gwyn, for the progress report, and Mr. Morgan, thank you for the very interesting presentation and also for the help you have been to the committee in the study and research on the subject of infra-red ray heating.

At this time I would like to introduce the new vice chairman of Committee 6, Kenneth E. Hornung, architect, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago.

For his outstanding service to the committee during the terms of five chairmen, I take this opportunity to introduce for the special recognition he deserves the secretary of Committee 6, Dan Converse, bridge engineer of the Akron, Canton & Youngstown Railway Company, Akron, Ohio.

Mr. Vice President, thank you for the kind reception of the report of Committee 6—Buildings, now concluded.

VICE PRESIDENT BROWN: Thank you, Mr. Urban.

We know as a result of the long illness and death of Chairman Perrine during the past year, that your committee has carried on with a heavy heart, but we congratulate you for the able way in which you directed the work of the committee in the absence of Mr. Perrine, first in your capacity of vice chairman, and subsequently as chairman. We welcome as your new vice chairman, Mr. Hornung, assured that Committee 6 again has good leadership, and will continue to carry forward its work on a highly productive basis.

We thank Mr. Morgan for the presentation of his slides.

Your committee is excused with the thanks of the Association. [Applause]

[President Meyers resumed the chair.]

Discussion on Maintenance of Way Work Equipment

[For report see pp. 417–468.]

[President Meyers presiding.]

PRESIDENT MEYERS: Few aspects of maintenance of way and structures work on the railroads have attracted more attention than the intensive mechanization which has taken place in nearly all track and structures maintenance operations, and this is just as live a subject today as at any time in the past. Our Association can be justly proud that it has a committee which has contributed immeasurably in this important development. I refer to Committee 27—Maintenance of Way Work Equipment.

The chairman is A. W. Munt, supervisor work equipment, Canadian Pacific Railway, Toronto. Mr. Munt, will you now proceed.

CHAIRMAN A. W. MUNT: Mr. President, members, and guests:

The report of Committee 27 will be found in Bulletin 547 on pages 417 to 468 incl. We are reporting on nine assignments, two of which are progress reports and seven of which are final reports. Eight of the reports are submitted as information only, and one report contains recommended revisions for inclusion in the next issue of the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment. The presentation of these reports is confined to brief summaries, but this committee hopes that those who are interested in work equipment will find the full reports both interesting and informative, and suggests that they be read in their entirety.

This committee invites pertinent comments from the audience. While we do not pretend to know nearly all there is to be known about work equipment, the subcommittee chairmen will do their best in an attempt to answer any questions you may wish to ask.

Assignment 1 (a)—Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment.

CHAIRMAN MUNT: The report on Assignment 1 (a) deals with the additional types of machines recommended for inclusion in the handbook. S. E. Tracy, superintendent of work equipment, Chicago, Burlington & Quincy, who is the subcommittee chairman, is unable to be present because of another meeting at this time. His report will be

presented by R. E. Berggren, supervisor maintenance of way and equipment, Illinois Central. Mr. Berggren.

PRESIDENT MEYERS: I think Mr. Tracy is escorting the ladies today on their trip. That is pretty important.

R. E. BERGGREN: Mr. President, fellow members, and guests:

To date 8742 copies of the 1957 revised edition of the handbook have been sold.

Investigation developed that the three units included in the report for this year have sufficient general distribution and use to justify publication of rules and instructions covering their care and operation. It is the recommendation that this material be included in the next revision of the handbook.

Assignment 3—New Developments in Work Equipment.

CHAIRMAN MUNT: The next report, on Assignment 3, represents an effort to include a brief description of all the new and important developments in the work equipment field during the past year. F. H. McKenney, engineer of track of the Chicago, Burlington & Quincy, who is the subcommittee chairman, is unable to be here because of illness. His report will be presented by J. W. Risk, superintendent of work equipment, Canadian National Railways. Mr. Risk.

J. W. RISK: Mr. President, gentlemen:

This assignment, as Mr. Munt said, covers a brief description of new developments in machines during the past year.

Your subcommittee is reporting on eight new developments which have been brought to its attention since the report of last year. Three of these are new machines which are directly applicable to track maintenance. These include a rail anchor applicator machine, radio-controlled spot board, and multi-tool tamper. Three other units, two of which are directly applicable to track maintenance, include a track surface wire indicator system for use with a jack-tamper, a wire line indicator for use with a track lining machine and set-off equipment which is applicable to both track and bridge and building maintenance. All of these are basically new devices for use with existing machines.

Two other units described are a bridge spray machine, and a rubber-tired crane. The former, being mainly applicable to bridge and building work, is a new adaptation of a pneumatic-tired air compressor for operation on track. The latter machine, which could be used for either bridge and building or track maintenance, is actually a regular rubber-tired crane to which flanged wheels have been added to permit operation on rails as well as off track and make the unit more flexible in its application to various types of work.

This is a final report submitted as information.

PRESIDENT MEYERS: It will be so received. Thank you, Mr. Risk.

Assignment 4—Improvements to Be Made to Existing Work Equipment.

CHAIRMAN MUNT: The next report is on Assignment 4 which covers a continuous study of ways and means to improve existing work equipment. The report will be presented by Subcommittee Chairman G. L. Zipperian, supervisor of work equipment, Great Northern.

G. L. ZIPPERIAN: Mr. President, members, and guests:

Your committee submits a report of progress as information which is a continuation of the reports submitted by this committee in previous years. It pertains to changes in existing work equipment that the committee has found to be both deseirable and practical.

This report covers the improvements which we suggest be made to 11 machines and which originated with members and others directly connected with the operation and maintenance of the machines.

These machines are:

Diesel pile hammer
Tie handler
Tie remover
Track broom
Ballast regulator
Combination tamper-jack
Track surfacing machine
Tie tampers, two types, production machines
Track liner
Multiple spike driver.

The improvements recommended in the report were submitted to the manufacturers of the equipment for their consideration. They expressed gratitude for the suggestions and advised that they would cooperate where possible in effecting the desired improvements. Many of the suggestions are now being incorporated in production-model machines.

PRESIDENT MEYERS: Thank you. Your report will be received as information.

Assignment 5—Instructions for Preventive Maintenance of Trucks.

CHAIRMAN MUNT: The next Assignment has to do with the proper maintenance of trucks. Subcommittee Chairman E. H. Fisher, manager of work equipment, Canadian National Railways, will present the report.

E. H. FISHER: Mr. Chairman, gentlemen: This is a final report submitted as information.

There are many preventive maintenance programs in existence covering motor trucks, and your committee is presenting information which should be helpful if you also desire to set up such a program.

The most important aspect of preventive maintenance is to have a thoroughly trained driver operating the vehicle. A suggested routine for the truck driver to follow is presented as a guide and is listed in the report as Exhibit "A". Two different preventive maintenance systems have been provided; the first is shown by Exhibits "B," "C," and "D," which are 2,500- 5,000- and 10,000-mile inspection intervals, respectively, and is a check-off type of report wherein the mechanic performing the inspection lists the work to be done as the inspection progresses. The estimated time required to carry out these inspections are 1 hr or less, 2 hr or less and 4 hr, in the same order.

The second system is shown by Exhibits "E," "F," and "G", Exhibit "E" being an inspection guide to be followed when lubricating vehicles. Exhibit "F" is the guide used when performing A & B preventive maintenance inspections, and Exhibit "G" is the report issued for defects found during the greasing or A & B inspections.

A suggested A & B inspection interval for high-mileage vehicles is 4000 miles, with two A inspections between a B inspection. For low-mileage vehicles, under 6000 miles, one B inspection per year. Estimated time required for inspection is 3 hr for an A and 5 hr for a B inspection.

It is considered that lubrication should be carried out at the time of inspection, if possible, and that the manufacturer's recommendations for the vehicle should be followed.

Many reputable tire dealers will gladly set up a preventive maintenance program for your tire requirements, and it is suggested that they be contacted in this regard.

It is not always possible to inspect vehicles in a garage, therefore, a field inspection procedure has been shown as Exhibit "F."

For further information and as a matter of interest, see pages 11 to 20, Sec. 2—Internal Combustion Engines, and pages 95 to 99, Trucks—Automotive, of the AREA Handbook of Instructions for Care and Operation of Maintenance of Way Equipment. Reference should also be made to pages 505 to 507, Vol. 55, and page 536, Vol. 56, of the AREA Proceedings.

PRESIDENT MEYERS: Thank you. Your report will be received as information.

Assignment 6—Equipment For Loading, Unloading, Transporting and Installing Continuous Welded Rail.

CHAIRMAN MUNT: The report on Assignment 6 covers a study of the most widely used types of equipment and practices for handling continuous welded rail. J. H. Brown, assistant chief engineer, construction, St. Louis–San Francisco Railway, who is the subcommittee chairman, will present the report.

J. H. BROWN: Mr. Chairman, gentlemen:

Subsequent to World War II there has been a definite trend toward the greater use of continuous welded rail by America's railroads. Due to this experience, various methods of loading, transporting, unloading, and installing continuous welded rail heretofore deemed impractical have been proved successful. Your subcommittee's report defines the most widely used and accepted practices of handling continuous welded rail.

At present from 17 to 37 standard-length rails are being welded and laid. The rail sections range from new 115 to 155-lb, with blank ends and without end heat treatment. In some instances railroads have justified the welding of lighter weight relay rail. This procedure requires transporting rails up to approximately 1500-ft lengths.

The continuous welded rails are usually loaded directly from the welding assembly line longitudinally onto cars by the use of a stationary single-drum hoist.

The capacity per train load varies, depending on the distances to be transported, the equipment available, and the extent of the season's program. Detailed explanations as well as pictures of the most widely used procedures and arrangements for securing the rails to flat cars for movement are included in the complete report found in the Bulletin.

Unloading welded rail is accomplished by track mounted lifting cranes placing the rail outside the track on tie heads or on the shoulder, and also by anchoring the end of the first rail to be loaded to existing track structure and laying the rail on the ground by moving the train out from under it.

Your subcommittee has concluded that there are many and varied techniques and appliances being used on the railroads of America today to accomplish virtually the same results in loading, transporting, unloading and installing continuous welded rail. The methods discussed in this report are the most generally accepted to date. This is a final report, submitted as information.

PRESIDENT MEYERS: Thank you, Mr. Brown. The report will be so received.

Assignment 7—Number of Units of Work Equipment to Be Repaired by Field Repairmen.

CHAIRMAN MUNT: The next report is on Assignment 7, which outlines an interesting study made in an effort to determine how many machines a mechanic can main-

tain in the field. Subcommittee Chairman S. E. Haines, Jr., port facilities engineer, Reading Company, will present the report.

S. E. Haines: Mr. President, members, and guests:

The number of units of work equipment to be maintained by one field repairman turned out to be a very controversial subject. Conditions varied greatly among the railroads. However, the report was deemed necessary because so many railroads had increased the number of their maintenance of way machines without making adequate provision for maintaining them.

This might best be illustrated by one of us purchasing a new automobile. This represents quite a sizeable amount of cash for most of us, and because it does we take care of the machine. We can drive the first 10,000 miles without doing more than changing oil and having it greased periodically. The car will still work if we don't renew the spark plugs, distributor points, and condenser, but it will become more and more difficult to start and eventually it won't start. In desperation we may run the battery down. At that time we will be forced to hire a mechanic. This will cost at least twice as much as if we had done some preventive maintenance and renewed the spark plugs, condenser, and points beforehand.

So it is with work equipment. We can run the machines until they require a major overhaul instead of routine maintenance, but in this case, instead of having only your wife angry with you because your car won't start, you may have 20 men standing by at more than $2 per hr, you may delay a few trains, and you may cause the division superintendent to develop another ulcer—all of this because you did not set up a preventive maintenance program.

There can be no hard and fast rules as to how many machines a field repairman can maintain, but using the experience of many railroads we have set up a guide chart, (see Bulletin 547, page 447) showing what others have done and the results which were obtained. We outlined in the preliminary report last year some of the factors involved and this year we came to our conclusions.

It is conceivable that a railroad with $1 million worth of work equipment, through neglect and a desperate attempt to save cash, might be forced to spend $200,000 for repairs. Whereas another railroad with a few mechanics might keep the same amount of equipment in repair for $50,000. This represents a saving of $150,000. Therefore, it is hoped that our report will be food for thought.

This is a final report submitted as information.

President Meyers: Thank you, Mr. Haines.

Assignment 8—Fuel and Lubrication Trucks for Use With Mechanized Gangs.

Chairman Munt: The next assignment deals with trucks specially equipped to handle the fueling and lubrication of machines used with gangs in the field. Subcommittee Chairman L. B. Cann, Jr., chief engineer, Richmond, Fredericksburg & Potomac Railroad, is unable to be with us because of other business. His report will be presented by M. D. Kerns, superintendent maintenance equipment—system, New York Central System.

M. E. Kerns: Mr. President, members, guests:

This is a final report, presented as information.

In recent years on many of the American railroads mechanization of track maintenance has made great progress. As more and more gangs became equipped with modern machinery the problem of supplying fuel and lubricants for this equipment has steadily increased.

The subject, "Fuel and Lubrication Trucks for Use with Mechanized Gangs," was assigned for study in 1958. It was determined that most of the roads were handling their fuel and lubrication needs with section trucks or pickup trucks to the point of work. One manufacturer which had designed a fuel truck for fueling diesel engines along the line of road and in heavy industrial areas has redesigned this truck in order to meet the needs for maintenance of way mechanized forces. The report on Assignment 8 covers, in detail, what is provided in this unit. Two of our larger roads in the east have designed and are building their own trucks to take care of this problem.

Our report covers, with pictures, the specifications for cab, chassis, and general equipment provided, and it is believed that with the information contained in the report any road would be able to design and build a truck to meet its particular needs.

It is felt that the same type of truck that is used in the mechanized timbering and surfacing gangs, with a few minor changes, can be adapted for use with larger grading forces employed in roadbed stabilization, bank widening and ditching work.

This committee sincerely hopes you will find the information both interesting and informative.

PRESIDENT MEYERS: Thank you, Mr. Kerns. Your report will be received as information.

Assignment 10—Four-Cycle Versus Two-Cycle Gasoline Engines Used on Small Equipment.

CHAIRMAN MUNT: The report on Assignment 10 covers an interesting study of the comparative merits of four-cycle and two-cycle engines. Subcommittee Chairman R. J. Smith, supervisor of motorcars, Chicago, Milwaukee, St. Paul & Pacific Railroad, is unable to be with us today. The report will be presented by T. H. Taylor, supervisor maintenance of way material and equipment, Northwestern Region, Pennsylvania Railroad.

T. H. TAYLOR: Mr. President, gentlemen:

With the large number of small gasoline engines in use for various applications on railroads today, the question often arises as to whether a four-cycle or a two-cycle engine should be used for a given application. The study of four-cycle versus two-cycle gasoline engines by your committee attempts to outline the comparative merits of each type and includes both air-cooled and water-cooled engines.

From the study made it is indicated that the small, air-cooled, two-cycle engine has its advantages for applications where light weight, simplicity of design, assurance of lubrication and all-angle operation is desired. Such applications might include portable chain saws, brush cutters, and similar machines. The water-cooled two-cycle engine is generally used for specific applications, such as track motor cars, where maximum torque at low speeds is desirable and the engine can be run in either direction without the use of a reverse gear. One of the major advantages claimed for the two-cycle water-cooled engine is that, due to its simple design, it can be maintained by anyone with a limited amount of mechanical ability.

The study indicates that the four-cycle air-cooled engine may be used to advantage where power requirements are constant for such applications as small track machines, pumps, generators, hoists, as well as track motor cars. The major advantages claimed for the four-cycle engine are: ease of starting, quiet operation, rated power periods longer, separate oil system resulting in cleaner burning fuel and longer sparkplug life.

Your committee hopes that the report on this assignment will be of some help to you in deciding on the type of engine for a particular application.

This is a final report, presented as information.

PRESIDENT MEYERS: Thank you, Mr. Taylor.

Assignment 12—Shop Machinery and Equipment Needed for Work Equipment Shops.

CHAIRMAN MUNT: The last report of this committee will be presented by Subcommittee Chairman J. W. Cummings, supervisor of work equipment, Delaware & Hudson Railroad.

J. W. CUMMINGS: Mr. President, Mr. Chairman, members, and guests:

From experience gained since publication of the previous report on this subject and the acquisition of many more complex and different types of machines, it is the opinion of the committee that the amount of equipment needed in a maintenance of way shop should be in direct proportion to the number of machines maintained by a particular railroad. This also applies to the number of machine tools which could be used in a medium or large shop.

Investigation develops that there is a wide range of opinion concerning this subject, but it is the consensus that the maintenance of way equipment shops should not attempt to manufacture repair parts or finished products in quantity where such items are readily available from suppliers at a nominal cost, unless special parts are required and delivery uncertain.

The regional shop should be set up to perform heavy specialized repairs to all classes of machines and should be equipped accordingly.

The district shop or small maintenance of way repair shop can perform other classes of work, which consist largely of replacing small parts, etc., where special machines are not required to make repairs.

With this arrangement, it is the opinion that machines can be maintained in the best possible condition.

This is a final report, submitted as information.

PRESIDENT MEYERS: Thank you, Mr. Cummings.

CHAIRMAN MUNT: Mr. President, that completes the reports of this committee and also my term as chairman. I would like to thank the members of this committee for their wholehearted and enthusiastic support during the past three years. The records will show that these men have produced a total of 24 reports during the past 3 years. I mention this to you merely to indicate that the members of Committee 27 are real hard workers and can handle any task assigned to them. Being chairman of this committee has been a pleasure and a most enjoyable experience.

In closing I would like to announce that the incoming chairman, F. L. Horn, engineer of track of the Terminal Railroad Association of St. Louis, because of other commitments, could not be with us today. R. S. Radspinner, supervisor roadway machines and equipment, Chesapeake & Ohio Railway is our new vice chairman.

PRESIDENT MEYERS: I found out this noon that Mr. Horn wasn't here. When we had our little gavel ceremony I looked down for Mr. Horn. I saw Mr. Radspinner standing there and Neal had a note in my papers that that was going to be the situation, but I hadn't read that far ahead yet, so I was stymied for a minute.

Mr. Munt, we want to thank you for the very informative reports that your committee has made this year and in the past. We are certainly indebted to you for keep-

ing us currently up to date on the developments in power tools and machines so essential to economical maintenance of way and structures work. We appreciate the effective leadership you have given for the past three years, and we are very happy to welcome Mr. Horn and Mr. Radspinner, who we know will continue to give able direction to the committee's work.

You are excused with the thanks of the Association. [Applause]

Gentlemen, I have an announcement to make. In case you are interested, the total registration up to 4 pm today was 1639.

Discussion on Economics of Railway Labor

[For report see pp. 385–416.]

[President Meyers presiding.]

PRESIDENT MEYERS: Having just heard a series of reports dealing with power tools and machines designed for maintenance of way and structures work, we will now hear the report of our committee that deals largely with the economies to be attained through the use of this equipment, both through the more efficient use of manpower and a higher quality of work. I refer to our Committee 22—Economics of Railway Labor, the chairman of which is L. A. Loggins, chief engineer, Southern Pacific Lines in Texas and Louisiana.

Mr. Loggins, will you please proceed.

L. A. LOGGINS: Mr. President, members, and visitors:

The report of Committee 22—Economics of Railway Labor, appears in Bulletin 547, pages 385 to 416 incl.

We will report to you on seven assignments, but first we want to pay tribute to two Members Emeritus of our committee who have died. One of these is W. H. Vance whose memoir appears with our report in Bulletin 547. The other is W. H. Brameld.

Briefly, the memoir for Mr. Vance states that he was born at Effingham, Ill., November 1876, and received a B.S. degree in civil engineering, University of Illinois, 1899. He had a colorful railroad career covering over 40 years with the Peoria & Eastern, and the St. Louis, Iron Mountain & Southern, the Lousiana & Arkansas, the Cotton Belt, and finally with the Missouri Pacific, on which he was assistant engineer maintenance of way at the time of his retirement in 1947.

He joined the AREA in 1911, was made a Life Member in 1946, and a Member Emeritus of Committee 22 in 1953. During his service with AREA he served two years on Committee 7—Wood Bridges and Trestles, and two years on Committee 12—Rules and Organization. Most of his work was with Committee 22, on which he served for 21 years.

Mr. Brameld was born in 1881 in England, and educated at Cooper Union, New York. His entire railroad employment was on the Erie from rodman in 1899 to assistant to chief engineer, maintenance of way, at the time of his retirement in 1946.

He joined the AREA in 1922, and became a Life Member in 1947. He served on Committee 3—Ties, from 1937 to 1949, Committee 20—Contract Forms, 1921 to 1936, was a member of Committee 22 from 1935 to 1950, and was made a Member Emeritus in 1953.

Assignment 2—Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work.

CHAIRMAN LOGGINS: The report on Assignment 2 will be given by Subcommittee

Chairman J. S. Snyder, assistant regional engineer, Southwestern Region, Pennsylvania Railroad, Indianapolis, Ind. Mr. Snyder.

J. S. SNYDER: Your committee during the past year studied operations on the Missouri Pacific Railroad that have substantially reduced the cost of labor required in its maintenance of way work. We inspected its concrete products plant and its timber fabricating plant at Little Rock, Ark., and observed the quality of the work accomplished at these plants.

Some years ago the Missouri Pacific started to renew its timber trestles with precast-pile and concrete-slab bridge construction. This work is being done by company forces working directly under the Missouri Pacific bridge engineer and the concrete products plant at Little Rock is an important part of his organization. The plant is operated by a foreman and 29 men and consists of a reinforcing steel storage yard where all the steel mats for the concrete piles and bridge slabs are assembled and tied. Adjacent to this area there is a reinforced concrete casting table for casting concrete piles. The table is complete with access ramps to permit the delivery of ready-mix concrete to the pile forms. Across the crane runway track and opposite the pile casting table, concrete bridge slabs are produced on a table designed for assembly line production methods, and again service roads and ramps are provided to permit pouring the slabs from ready-mix trucks. The plant is also set up to produce backwall segments and signal foundations. In all cases specially designed steel forms are used to simplify and expedite the manufacture of these concrete products.

Seven 24-in concrete piles ranging from 20 to 55 ft in length are produced daily. The forms are stripped the second day and the piles are moved to storage yard the third day. The piles are produced and stored according to requirements for the anticipated program of bridges for renewal. Concrete bridge slab production works from both ends of the table and when the center forms are filled the end slabs are 5 days old and can be removed from the table and stored and the operation repeated. The slabs vary in length from 15 to 24 ft, and two slabs are produced each day.

Signal foundations are cast utilizing surplus concrete left after the bridge slabs are poured. The Missouri Pacific has found it is more economical to use ready-mix concrete at the bridge site whenever possible; however, in locations not accessible to trucks they have equipped a flat car with a ½-yd capacity mixer, batch bins, water storage and conveyor facilities designed to produce 25 cu yd of concrete without recharging the car.

We also observed the procedure for applying molten zinc to the top surfaces and edges of steel bridge members that are subject to excessive brine damage. The committee was then given an excellent opportunity to inspect a concrete trestle bridge, which is the type of structure produced in the concrete products plant at Little Rock.

Little Rock Junction bridge, consisting of 11 panels and a total length of 208 ft, was constructed in 1946 and replaced an 18 panel untreated pile trestle bridge, a total length of 215 ft.

The actual cost of this bridge in 1946 was $21,756, or approximately $105 per lin ft of bridge, and the estimated cost of a similar structure using 1958 wages and material prices would be $38,100 or approximately $183 per lin ft.

These attractive cost figures show the results of excellent planning and supervision on the part of Missouri Pacific to reduce its cost of replacing wooden trestles with concrete pile trestles. With this program in effect to replace timber trestles with concrete pile trestles, the need for preframing bridge timber has been reduced considerably, and in 1955 the timber preframing mill was enlarged to accommodate the manufacture of full-depth plank highway crossing units. The plant is operated by a unit of the division

bridge and building gang and consists of an assistant foreman and 12 men. The gang works under the supervision of the Arkansas Division bridge and building supervisor, collaborating with the treating plant superintendent.

The committee inspected the timber preframing mill and observed the manufacture of the solid timber plank crossings and then inspected a recent installation of a prefabricated full-depth timber crossing at Forbing Road, Ensign, Ark. The two main-line tracks at this crossing were completely rebuilt and ballasted with stone ballast, and new 132 RE rail was installed with the joints laid tight. New creosoted ties were installed on 19¼-in centers, fully tie plated and further protected with tie pads.

The committee also observed the operation of a tie renewal gang while at Forbing Road. The tie renewal gangs precede and work independently of the surfacing gangs and, as a rule, ties are renewed only where renewals exceed 300 ties per mile.

The tie renewal gang is so organized that all machines can be removed from the track and replaced by the gang easily and quickly ahead of a train, and very little time is lost clearing for trains. The special track gangs work without flagmen, and train crews are given a train order to reduce speed to 30 mph, prepared to stop where gangs are working. The foreman works closely with the tower operator and gives a hand signal to the train crew to proceed when the gang is in the clear.

The Missouri Pacific has programmed the replacement of its worn-out timber trestles with permanent concrete pile and slab bridge construction in a most economical and efficient manner. The permanency of this type of structure, requiring little or no maintenance, has proved to be a sound investment as compared to the use of timber construction requiring renewals in a continually rising material and labor market. It is concluded that under conditions similar to those encountered on the Missouri Pacific, substantial labor savings may be realized by the replacement of wooden trestles with those of reinforced concrete design.

This road has also made substantial savings in labor by prefabricating full-depth timber highway crossings at a centralized framing plant. It also has progressed the design of new equipment and machinery, such as a tie car and spiking machine, that have been most effective in the economical use of maintenance of way forecs.

Assignment 3—Labor Economies to be Derived from Cyclic Maintenance.

CHAIRMAN LOGGINS: Report on Assignment 3 will be given by H. W. Seeley, engineer maintenance of way, Detroit, Toledo & Ironton Railroad, Dearborn, Mich.

H. W. SEELEY: Mr. Chairman, members and guests:

The cyclic method of maintenance has greatly increased the savings that were first made possible by mechanization, but most railroad cost information is not detailed enough to separate the savings that can be attributed directly to mechanization from the savings reslulting from cyclic maintenance.

Based upon the opinions and experiences of the 29 railroads that furnished information for this report, the following conclusions as to the labor economies to be derived from cyclic maintenance may be reached:

1. The resulting more uniform quality track and better general standard of maintenance will reduce the amount of labor required for spot surfacing and spot tie renewals.

2. The necessary long-range programming and budgeting will result in reduction in inventory, savings in labor for material handling, more stable force and greater utilization of available machinery.

3. Fewer gangs and working units will permit closer supervision and better organizations, resulting in increased production per man.

4. Fewer gangs, on some railroads, will cause less traffic interference and may make it possible for operating departments to permit more uninterrupted working time, resulting in increased production per man.

It must be recognized that short term programming and budgeting may disrupt this type of maintenance program to the extent that much of the economy would be lost.

The physical condition, the riding quality and the standard to which it is desirable and economical to maintain these conditions will generally be dependent upon the tonnage, speed, and class of traffic that the track will carry, and will determine the length of the maintenance cycles. Once the cyclic method of maintenance is established, the greatest economy that can be directly attributed to it will result from correctly determining the most economic length of cycle necessary to maintain the railroad to the standard required and, at the same time, to permit the work to be accomplished economically with the organization and equipment that is available.

PRESIDENT MEYERS: Thank you, Mr. Seeley.

Assignment 4—Relative Advantages of Renewing Ties in Advance of Out-of-Face Surfacing with a Mechanized Tie Gang, Compared with Renewing Ties with a Surfacing Gang.

CHAIRMAN LOGGINS: The report on Assignment 4 will be given by Claude Johnston, assistant to vice president, Birmingham Southern Railroad, Fairfield, Ala.

[Claude Johnston read in full the report on Assignment 4 as printed on pages 404–406, Bulletin 547, same pages these Proceedings.]

PRESIDENT MEYERS: Thank you, Mr. Johnston. I don't know of any item that is more controversial or questionnable than this. I have been trying for two years on our own road to decide which is the best method.

I have come to the conclusion that you have to take every operation into consideration, even though one will show you that you should do it one way and another will show you that you should do it the other.

Assignment 5—Labor Economies to be Effected Through the Use of Power Tools and Mechanized Equipment by Bridge and Building Gangs.

CHAIRMAN LOGGINS: The report on Assignment 5 will be given by W. E. Chapman, chief engineer—maintenance, Central of Georgia Railway, Savannah, Ga.

W. E. CHAPMAN: This prograss report on labor economies to be effected through the use of power tools and mechanized equipment by bridge and building gangs, in view of increased cost of materials and labor, and the need for keeping outgo of monies within the limits of income, is of interest to all carriers. Of necessity, it covers only those tools found by certain reporting carriers to be the most economical.

Equipment for various gangs is shown as follows:

For unloading bridge material at the site of use—A bridge hoist or crane, which shows considerable economy.

For timber bridge gangs—One hydraulic hoist mounted on a heavy-duty truck with a complement of hydraulic tools which increases production 3½ times.

All trucks mentioned herein have retractable rail wheels.

For steel and concrete bridge gangs—A bridge hoist mounted on a heavy-duty truck, an air compressor with tools, portable platforms and scaffolding, with which production has been doubled.

For bridge greasing gangs—One properly equipped production spraying machine with spider staging which greases about six times as many tons of structural steel as

was done with brush work due to increased speed and the fact that greasing is a one-coat operation requiring a minimum of precleaning and providing equal protection for a comparable period of time.

For a bridge deck coating gang—One properly equipped production spraying machine with a gravel distributing attachment which makes possible an increase in production up to 2½ times over that of previous machines.

Spraying of structural steel and coating of decks is done during the warmer months and bridge repairs made during the cold months; hence, all equipment except sprays and pumps is used throughout the year.

For building paint gangs—A hydraulic serial boom mounted on a heavy-duty truck, properly equipped, with which 8 times as many yards of wall area can be painted as can be done with scaffolds.

For carpenter gangs—One trailer, enclosed on all sides and arranged so that sides may be raised to form a roof over the trailer floor which serves as a work bench, a power plant and necessary tools which are producing 2½ times the amount of work done previous to the use of such equipment.

All gangs are housed in highway trailers parked at or adjacent to the work.

All gangs are equipped with radio communication.

Summarizing, many combinations of the equipment and tools described can be made, depending upon the size of the carrier, and its contractural and maintenance requirements.

One of the most important results of mechanization is the realization of the full abilities of men throughout the entire working day, as machines have practically eliminated all arduous labor.

The over-all reduction in bridge and building expenses due to the acquisition and use of the above tools and equipment approaches 70 percent.

PRESIDENT MEYERS: Thank you, Mr. Chapman.

Assignment 6—Labor Economies to be Derived from the Use of Radio by Maintenance of Way Gangs.

CHAIRMAN LOGGINS: H. M. Williamson, engineer maintenance of way and structures, Southern Pacific, and chairman of Subcommittee 6, was unable to attend the meeting, so I will give his report.

The information developed at this time discloses that there was nothing new in this field since the last AREA report on the subject, which appears in the Proceedings, Vol. 59, 1958, pages 590 to 592 incl.

It is the recommendation of your committee, therefore, that this subject be discontinued for a period of several years or until such time as it justifies resuming.

PRESIDENT MEYERS: So received.

Assignment 7—The Specific and Ultimate Improvements In Various Types of Track Maintenance Equipment That Would Provide the Greatest Economies in Maintenance Practices, and How These Potential Economies Would Compare With Present Costs, Collaborating with Committee 27.

CHAIRMAN LOGGINS: The report on Assignment 7 will be given by P. A. Cosgrove, division engineer, Illinois Central, Champaign, Ill.

P. A. COSGROVE: Mr. President, members of the Association, and guests:

Our report on Assignment 7 lists the improvements recommended for track maintenance equipment compiled from replies received from 13 railroads to a questionnaire we sent to 40 roads.

It is our opinion this is an important subject at this time when all railroads are attempting to bring about all possible economies. In view of the fact that this is a progress report, we sincerely request all railroads receiving our questionnaire during 1959, to furnish replies indicating the potential economies to be derived from any improvements they may recommend.

The continued development of ideas such as those presented in this report will give us increased production with reduced cost of work accomplished.

PRESIDENT MEYERS: Thank you, Mr. Cosgrove.

Assignment 8—Labor Economies to be Derived from the Use of Various Machines Available for Calculating and for Lining Curves.

CHAIRMAN LOGGINS: Report on Assignment 8 will be given by M. B. Allen, division engineer, New York, Chicago & St. Louis Railroad, Frankfort, Ind.

M. B. ALLEN: Mr. President, members, and guests:

Information furnished by maintenance officers on 45 railroads indicates that few comprehensive time studies have been made of the work of either staking curves or actually lining them. Only one road furnished such a report.

Approximately 90 percent of all main-track curves are string lined, mechanical full-throw computers being used on slightly more than half of these and mathematical computing of several kinds being used on the remainder.

Mechanical or graphic computers reduce the computing time as compared to mathematical computing by 50 percent, and the better balanced, smaller throws which are obtained by their use makes it possible to realize considerable labor economies in actually shifting the track.

Stakes are set on approximately two-thirds of the curves, and throw meters or "scratch-boards" are used on approximately one-third. Also, one-fourth of the roads use a mechanical device for measuring ordinates.

One-half of actual shifting of track is done by power machines and the other half is done solely by manpower. So-called on-track machines and portable machines are used, generally in conjunction with other machines, in out-of-face surfacing and timbering operations. The economies which result from use of power lining machines varies considerably, depending upon how the machines are used. If used in conjunction with other machines, no flagmen other than those used for the entire operation are required, and lining may be done by 1, 2, 3 or 4 men, in place of the 10 or 15 usually required using manpower. If on-track machines are used singly, the expense of the machines, the foremen, the flagmen and operator may closely approximate the cost of doing the work by manpower. Portable lining machines are perhaps more adaptable to single use, as no flagmen are generally required and such use results in approximate savings of 40 percent as compared with lining by manpower.

An attachment for an on-track lining machine which permits the lining of curves without computing throws or shifts, has been introduced recently. Also, a new graphic system for computing half throws without use of numbers or computations is in limited use on several railroads. Either or both of these developments may in the future affect or change present curve-lining practices, but there is not sufficient information at this time to determine the ultimate economies which might result from their use.

There is general agreement that the use of either mechanical or graphic computers reduces the calculating time by 50 percent, and the use of power lining machines results in 60 percent reduction in labor as compared to the use of manpower.

This is a final report, submitted as information.

PRESIDENT MEYERS: Thank you, sir.

Assignment 9—Relation Between the Nature of Traffic and the Interval Between Out-of-Face Resurfacing of Tracks of Relatively Similar Characteristics.

CHAIRMAN LOGGINS: The report on Assignment 9 will be given by R. W. Pember, assistant division engineer, Louisville & Nashville, Birmingham, Ala.

[Mr. Pember read in full the report on Assignment 9 as presented on page 416 of Bulletin 547, same page these Proceedings.]

PRESIDENT MEYERS: Thank you, very much.

CHAIRMAN LOGGINS: That concludes our subcommittee reports, but we have a special feature, a talk to be made by a member of our own committee, H. J. Fast.

First I would like to say a few things about Mr. Fast, who has had a very colorful career. He was born in Puchova, Russia, received his early education in the schools in Europe, attended high school in Collonsay, Sask. He worked in the gold mines of the Porcupine area in northern Saskatchewan, and the Northwest Territories. He entered railway service in 1938 as a continental representative of the Canadian National Railways in Europe, the Baltic states and Scandinavian countries until 1939. He received his B.S. degree in geology in 1940 from the University of Saskatachewan. In 1940–1941 he was resident engineer and geologist in the Negas gold mines, Yellow Knife, Northwestern Territories.

His subsequent railroad career with the Canadian National Railways varied from instrumentman to assistant chief engineer, which position he held until the first of this month. He is now coordinator of work study, System, Montreal, Que. He has been a member of AREA since 1946 and a member of Committee 22 since 1951.

Mr. Fast is going to give a report on work study—a tool for railway management as practiced on British railways. Mr. Fast.

Report on Work Study—A Tool For Railway Management As Practiced on British Railways

By H. J. Fast

Coordinator of Work Study, System, Canadian National Railways

Mr. President, Mr. Loggins, members and guests:

Because of the many reports and lectures given at a convention of this kind it is necessary that we keep one eye on our watches so as not to run late. For this reason, I will dispense with the usual introductory stories and get on with my remarks on the subject assigned to me for presentation to this convention.

In April last year I had the opportunity to visit Southern Europe and England. I obviously looked around to see what the railways were doing whenever I crossed a right-of-way or rode on a train. Since this convention has heard a number of excellent reports on European Railways in recent years, I will confine my remarks to a specific experiment carried out on British railways.

In England, as in Europe, there is considerable activity in up-grading and modernizing the railways. In fact, there is now a modernization program in progress estimated to cost 1,200 million pounds. Whereas a great deal of planning went into this program by way of modernizing the physical plant, much attention was also given to matters of personnel. One phase deals with productivity.

One of the problems of British railways is availability of track to carry out maintenance. There are many densely populated centers where traffic is fast and frequent. I observed a gang working at one such location where there were four main lines and a train every minute and a half. Theoretically one can assume that average time available between trains on any one track is 6 min. Needless to say "on-track" power tools are useless. Such traffic density coupled with other conditions make it necessary to do much of the work with hand tools.

This situation led to an intensive study of work methods and resulted in the adoption of what is now commonly known as "Work Study." This can be defined as a critical and intensive examination of work operations (repetitive or otherwise) to improve methods of operation. So frequently we grow up with work methods that we believe as most effective. However, examining these with well known techniques, such as time and motion studies, process charting, work measurement and others, we find that we are in error. Or, stating this another way work, Work Study has proven that wherever human activities have been organized, it has too often been the practice to accept opinion in place of fact and decisions made on what was *thought* to be true instead of what was *known* to be true.

It has been the popular belief that these techniques are applicable only to repetitive work on assembly lines. However, in England they have been applied to routine maintenance such as surfacing, renewing ties, tightening bolts, etc., on the track; redriving rivets, replacing corroded steel members, etc., on bridges; and effecting all manner of routine repairs on shops and buildings.

This work was pioneered on the Southern Region. Today 75 percent of all track work on this region is under Work Studied schemes. Progress is also being made on the other regions. In fact 25 percent of the system mileage is under this scheme, comprising some 12,000 employees. It takes some time to train personnel and become organized. Once this is done progress is rapid. As an example, the progress, including all departments from 1947 to 1958, was as follows:

	No. of Schemes Implemented	*No. of Schemes Under Consideration*
October 1957	38	59
October 1958	274	231

To outline the procedure adopted on British railways from the grass roots up through the various levels of administration to regional headquarters and the offices of the British Railway Commission would be time consuming indeed. Suffice it to say that each job starts with an examination by a supervisor or qualified inspector who submits a very detailed report of what has to be done. This is turned over to the Work Study group which makes an appraisal and designs the job in every detail, including methods and schedule of work. It is then turned over to the supervisor for action. When the foreman and his gang arrive, the material and tools are there and he is given the flow sheet prepared by the Work Study group. There is no delay. Both he and the supervisor know what has to be done. Each day he submits a progress report which is summarized for review and appraisal by various levels of management.

All this seemed cumbersome and unwieldly to me, so I decided to take a personal look at the whole scheme, and the best place to start was at the grass roots in the field and follow through to at least district office level. I found that in practice the procedure is simple. Each man does his bit and no one is unduly burdened. The total staff required to administer the scheme is approximately 4 to 5 percent of the total payroll. It should

be mentioned here that the employees under this scheme are receiving incentive pay, and those engaged in processing payrolls for this purpose are included in the 5 percent.

The additional payroll expense is offset through greater productivity, and the net gain over former methods is estimated at 20 percent. It would, therefore, appear that the company enjoys benefits through greater productivity. But what about the officers and men? I proceeded to ask them. The foremen told me they liked it because the work was now properly planned and scheduled. Each day they knew exactly what to do and how it should be done. The schedules proved to be quite realistic, and they knew on Monday where they would be on Saturday. It also gave the foreman a chance for closer supervision of the men since they did not have to spend as much time in arranging and planning the work.

The supervisors liked it because they now had staff to assist in planning and executing work and, in addition, maintaining reliable records. The Work Study staff was also of great assistance in arriving at the best possible solutions for each job.

The details prepared and used on the job and the reports of work done are variously summarized for higher levels of supervision and administration. The data shown on the reports seemed to be comprehensive and should be of considerable aid to senior officers. As an example, one of the reports was in the form of a chart employing colors and symbols. A brief glance was sufficient to know how work had been done, the location, cost and frequency over a period of several years. Such a chart would be of great assistance to any inspection party.

After I had observed several Work Studied projects and examined the reports, I asked to be shown an example of a facility which would indicate a "before" and "after" situation. Since I was in the vicinity of Southampton I was taken to a yard nearby. The Work Study group in its investigation came up with a solution for this particular yard which they felt should improve the standard of maintenance and yet employ less manpower. At the time of my visit the new method had been in effect for several months. The same foreman with less men had already upgraded the standard of maintenance for nearly half the yard and the difference was obvious. I should state here that in this particular yard the only change made was in method of doing work. The tools and materials used were the same.

Whereas I have made reference primarily to routine nonrepetitive work, I also had an opportunity to observe work in shops which was repetitive. Most of us feel that it is elementary to set up an efficient operation where work is repetitive. On the Southern Region, I saw one such operation in a reclamation yard. Because of traffic density, track is changed out by replacing complete panels. The released panels are shipped to a reclamation yard for dismantling and salvage. In this operation, there was a gang whose function it was to remove the rail chairs from the ties and then sort and stockpile the various component parts. The job was laid out in a series of work stations at which each man performed a specific task. The Work Study group appraised this job and found that for this particular operation the assembly line principle was wasteful. They found that by feeding the ties to the men (working in pairs) in bundles and have them follow along performing a different task at each work station would improve productivity about 40 percent.

From this it would appear that no matter what the job is there may be room for improvement. All of us should take time off to sweep our minds clear of tradition and prejudice, step outside the right-of-way, and from a distant vantage point appraise the tasks for which we are responsible. I am sure we would find a waste of manpower here and there.

To sum up, it can be stated that the formalized application known as Work Study to routine maintenance in way and structures, as adopted on British railways has increased productivity and that it was not the result of working *harder* but working *smarter.*

I have since had an opportunity to attend the Executive Conference on Work Simplification at Sea Island, Ga., directed by Allan H. Mogensen of Lake Placid. There is not time to present the philosophy of work simplification as developed by Mr. Mogensen and associates. Suffice it to say that many and varied industries have had success with work simplification as an aid to management.

Mr. President, Mr. Loggins and gentlemen, I thank you for your attention. [Applause]

CHAIRMAN LOGGINS: Thank you, Mr. Fast, for a very interesting report.

This completes the report of Committee 22.

PRESIDENT MEYERS: Thank you, Mr. Loggins. Your committee continues to be one of the so-called "more popular" committees of our Association, the reason for which is pretty evident from the character of the reports which you present from year to year, some of which are based upon interesting inspection trips to observe operations in the field. The Association is indebted to your committee for its many reports in the past, and for the interesting and informative reports which it has again presented this year. Under your leadership, Mr. Loggins, I am sure Committee 22 will continue to be one of the "more popular" committees of the Association.

And, thank you, Mr. Fast, for your interesting report on how the British railways analyze work operations as a tool for railway management. This was most interesting.

Mr. Loggins, your committee is now excused with the thanks of the Association.

Discussion on Ties

[For report see pp. 497–500.]

[President Meyers presiding.]

PRESIDENT MEYERS: In our last report for today, we will hear from one of our committees which specializes in one of the more important elements of the track structure. This is our Committee 3—Ties, the chairman of which is F. J. Fudge, timber engineer, New York Central System, New York. I will be pleased if Mr. Fudge and members of his committee will now present their report.

CHAIRMAN F. J. FUDGE: Mr. President, members, and guests of the AREA:

The report of Committee 3 is printed in the December Bulletin, No. 547, beginning on page 497, and in the June–July Bulletin, No. 544, beginning on page 129. The committee is reporting on four of its eight assignments.

Assignment 4—Tie Renewals and Costs Per Mile of Maintained Track.

CHAIRMAN FUDGE: The report on Assignment 4 will be presented by Subcommittee Chairman L. W. Kistler, tie and timber agent, Frisco.

L. W. KISTLER: Mr. President, members, and guests:

The AAR anual cross tie statistics as compiled by the Bureau of Railway Economics show only 21,525,233 new wooden cross ties inserted in track by the Class I Railroads of the United States. This was a reduction of 1,724,216 from the previous year, or 7.42 percent, and is the smallest annual quantity inserted during the approximately 60 years of AREA existence.

Equated gross ton miles per mile of track was off 3.54 percent, or 241,000 tons. Thus, while the downward trend in cross tie renewals is due primarily to the benefits of efficient wood preservation and a higher quality of track maintenance, yet the reduced traffic (earnings) in 1957 undoubtedly was a dominant factor in the reduction mentioned.

Perhaps the following table of comparisons showing the "Low" region, the "High" region and the United States averages will be of interest.

	"Low" Region	*"High" Region*	*United States Averages*
Inserted in 1957 Ties per Mile	46 New England	88 Southwestern	67
Change 1957 from 1956 Tie Insertions per Mile	12 Less—Southern	4 More Pocahontas	5 Less
Average Annual Insertions Per Mile 5 Year Average 10 Year Average	50.8 New England 61.1 New England	102.2 Southern 116.8 Southwestern	74.2 84.3
Average Cost Per Tie Increase 1957 over 1956	$3.04 Southwestern 0.04 Great Lakes	$3.96 Central-Eastern 0.34 Central-Eastern	$3.62 .18
Tie Cost per Mile of Track	$167. New England	$302. Southern	$243.
Equated Gross ton-miles per Track Mile (thousands)	4.236 Northwestern	11.818 Pocahontas	6.576
Estimated Average Life Based on— 5 Year Average Renewals 10 Year Average Renewals	*Years* 29.83 Southwestern 25.86 Southern	*Years* 59.13 New England 49.16 New England	*Years* 40.67 35.80
Number Ties per Mile used in above calculations	3,049 Southwestern 3,021 Southern	3,004 New England	3,018

One of the more interesting points in the above tabulation is that the average computed service life, based on the 10-year average for the "high" New England region is 49 plus years, almost double that of 25 years for the "low" Southern region. Unquestionably, the longer warm humid seasons of our southern areas are more conducive to decay and tie deterioration than in other sections and continues to present a challenge to our wood preservation efforts.

There are some "tie experts" who are firmly convinced that a number of railways are in their low cycle of renewals and under normal circumstances will have increases in the near future. Thus the many variable and other factors involved affecting cross tie insertions make interpretation and evaluation of these statistics most difficult and hardly permit one to draw mathematical conclusions, or to make effective comparisons between individual railroads.

Nevertheless, the statistics are quite valid in determining trends, and the long term trend is definitely down, although it appears we may be approaching a "floor," or even a low point in the renewal curve.

I have computed the 10-year average renewals per mile of track (which is perhaps a truer index than the 5-year average) for the years 1945 thru 1957 and find that each year it has been lower than the previous year. This 10-year average for 1945 was 135 ties per mile; 5 years later it was 121.6 in 1950; still further, reduced in 1955—10 years later—to 92.9, and in 1957 was 84.3. This was a reduction in 12 years of 50.7 ties per

mile, or 35 percent, and one which must be encouraging to maintenance officers trying to stretch allowances

This is presented as information.

PRESIDENT MEYERS: Thank you, Mr. Kistler.

Assignment 5—Methods of Retarding the Splitting and Mechanical Wear of Ties, Including Stabilization of Wood, Collaborating with Committee 5.

CHAIRMAN FUDGE: G. M. Magee, director of engineering research, AAR, will summarize the work completed by the National Lumber Manufacturers' Association, collaborating with Committee 5, on the methods of retarding tie splitting and the mechanical wear of ties, including stabilization of wood.

G. M. MAGEE: Mr. President, members, and guests:

Last year the Timber Engineering Company staff prepared a final report on the 10-year investigation for prolonging the service life of cross ties, which was completed in 1957. This research was sponsored and financed jointly by the NLMA and the AAR. It is proposed to publish this report as an advance report of the Tie committee in one of the summer bulletins.

One of the more important results of the investigation was the combined seasoning and treating process for treating green ties. Two-thousand ties have been treated by this process by the Pennsylvania and Illinois Central Railroads and installed in main-line track for service test. The patent on this process has been dedicated to the public.

Another result was the study and exposure tests of tie coating materials and development of a specification therefor. A design of laminated tie was developed and 120 ties were produced and installed in heavy-duty track on the Pennsylvania Railroad for observation of service performance. Another significant finding was the deteriorating effect of corrosion products from tie plates and spikes on the wood fibers. All of these results and others are fully described in the report.

PRESIDENT MEYERS: Thank you, Mr. Magee.

CHAIRMAN FUDGE: H. M. Sutcliffe, research technician, research staff, AAR, collaborating with Subcommittee 8, will address the Association on the subject, "Studies of Anti-Splitting Devices for Ties at the AAR Research Center."

Studies of Anti-Splitting Devices for Ties at the AAR Research Center

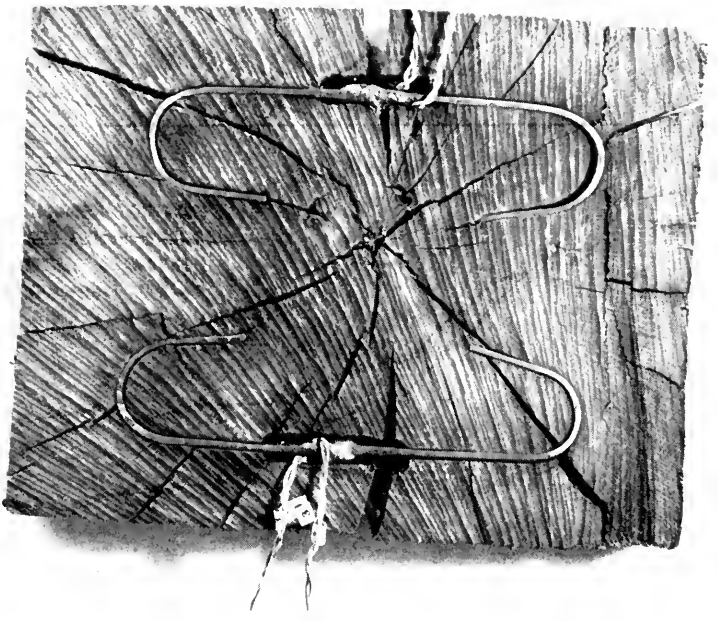
By H. M. Sutcliffe

Research Technician, Research Staff, AAR

This project on evaluating the effectiveness of anti-splitting devices was started because of the varied opinions as to their effectiveness in retarding end splitting in ties.

Most railroads today apply some sort of anti-splitting device to their ties. Some roads which had been using anti-splitting devices in the past have quit using them, except on a selective basis to salvage ties which would otherwise be rejected. Others have changed from the use of C- or S-irons to doweling, which costs almost twice as much as applying end irons.

It would be difficult to get anyone to place a specific monetary value on the benefits derived from the use of anti-splitting devices. Most people will agree that anti-splitting devices provide some protection, especially to the ties which are the more prone to splitting. They would also agree that some ties would never split enough to derive any benefit from any device.



Slide 1—Strain gages mounted on C-irons to measure the stresses transmitted to the iron.

The question facing us is whether anti-splitting devices should be used out-of-face, selectively, or not at all, and if they are to be used, which device is best.

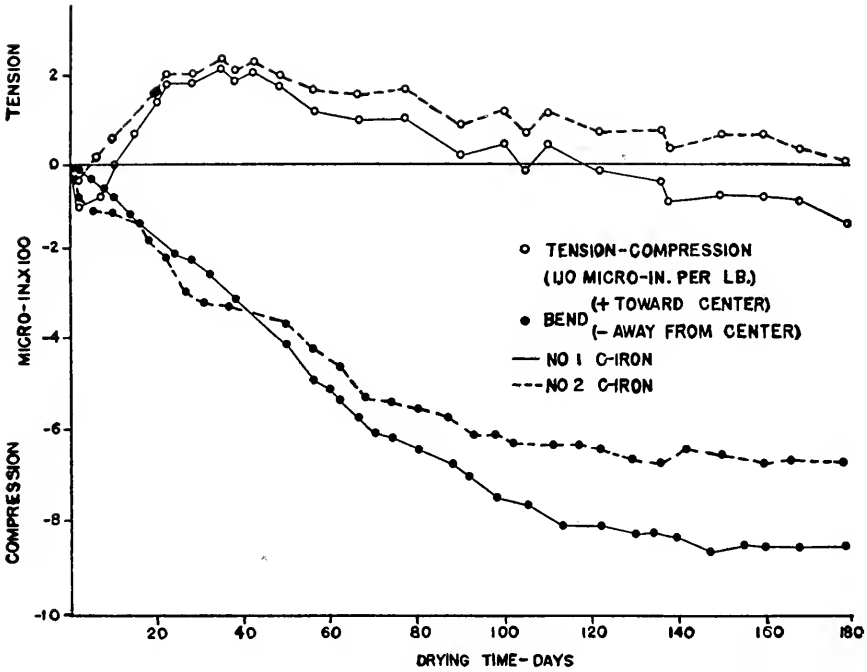
The Forst Products Laboratory at Madison, Wis., has established that splitting is a function of shrinkage and that shrinkage occurs only when the moisture content of the wood drops below 30 to 35 percent, depending on the species.[1] Too, the tangential shrinkage along the growth rings is greater than the radial shrinkage perpendicular to the growth rings. It is uneven shrinkage which sets up stresses in the wood greater than its bonding strength to cause a split.

All anti-splitting devices have been designed to resist the splitting forces which develop when the wood shrinks. Until the wood splits enough to offset the shrink which caused the split, the device cannot be effective in preventing a split. The best that can be expected is that the device will limit the size of the split.

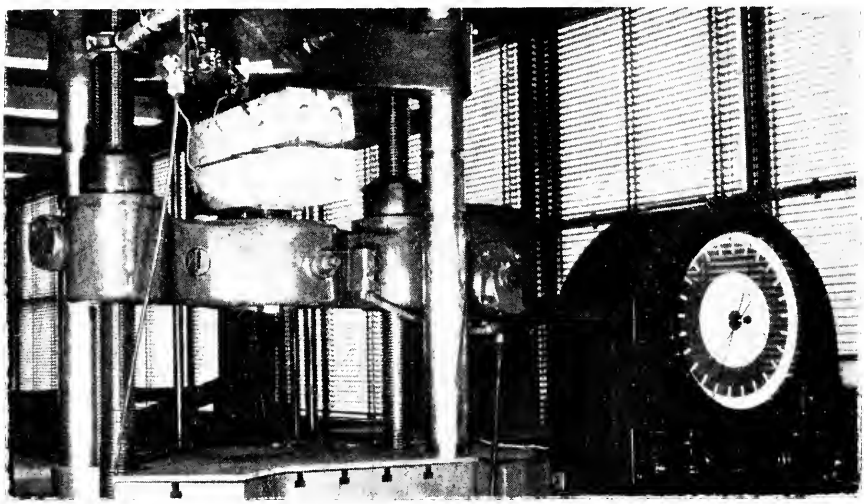
In the laboratory, accelerated seasoning tests were conducted (1) to compare the effectiveness of the various anti-splitting devices, (2) to study the kind and amount of forces which come into play on the anti-splitting devices as the tie shrinks during seasoning and (3) to measure the holding power of the devices. Red oak ties were used in most of these tests.

In the accelerated seasoning tests, full ties were cut in half. The device was applied to one half and the other half was left as a control. The extreme variation in the

[1] Shrinking and Swelling of Wood in Use, Report No. R736 (Revised) USDA, Forest Service, Forest Products Laboratory, Madison, Wis.



Slide 2—Stress development on C-irons during accelerated seasoning.



Slide 3—Pull test specimen in Baldwin testing machine.

splittability of individual ties made any comparison very difficult. While it could be seen that some of the devices provided some protection, no comparison between them could be made directly.

An attempt was made to relieve the stresses which build up in the wood as it dries, rather than to try to restrain the stresses with mechanical devices. This was done by kerfing the ends of the ties with saw cuts. In all, five designs were tried. No design was completely effective, but some protection was afforded by most of them.

In order to measure the stress which the wood transmits to the anti-splitting device, strain gages were mounted on S-irons, C-irons and dowels. Gages were mounted on both sides of each device near the center. Flat sections had to be milled on the dowels to provide a suitable surface for mounting the strain gages, and the electrical leads from the strain gages were fed through an axial hole in the dowel to bring them outside of the tie.

Slide 1 shows how the wood was routed out at the gage position for the C and S-irons so that the gage would not be damaged when the iron was driven.

The manner in which wood shrinks to cause splitting can readily be seen. Notice how the wood inside the curve of the iron has shrunk away, yet the wood on the outside of the curve is tight against the iron. This shows that the wood on the outside of the curve is relatively in the same position as when the iron was driven. However, in relation to the iron, the wood at the split has moved. Even with a split of this size, this iron is in compression, not tension.

Slide 2 shows the stress development on the C-irons, which was typical of the group. The shrinkage of the wood put the device into compression for the first few days. After that splitting occurred to put the device into tension, which shows that the device was resisting the splitting action. As the wood continued to shrink, the tension rose to a peak then declined into compression again. Some did not quite reach compression the second time. And others remained in compression from the start. Considerable bending was experienced in all of the ties.

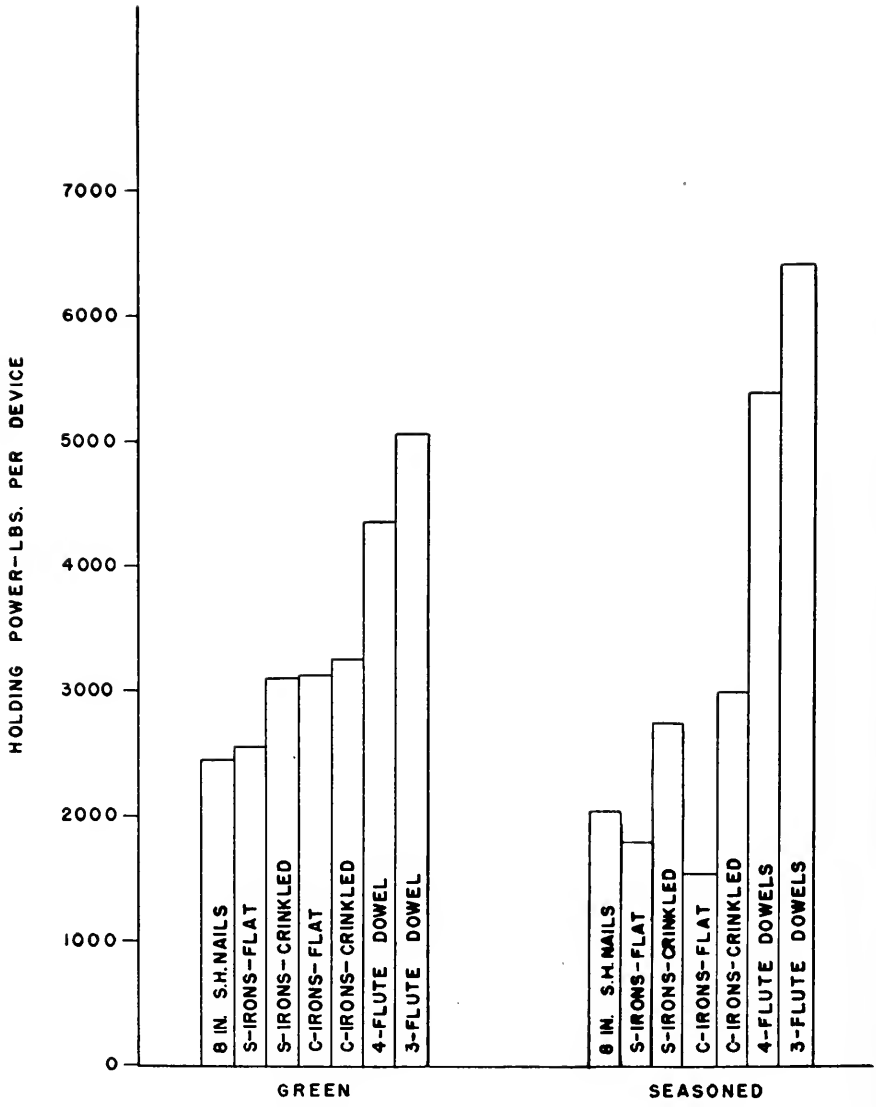
The maximum load developed in the C and S-irons was only a little more than 200 lb. In the dowels driven 6 in from the end an 800-lb load was recorded on the strain gage. For the dowel driven 3 in from the end the maximum was 1400 lb.

To measure the holding power of the various devices, two types of pull tests were made. In one test 22-in sections of green red oak ties were ripped along the 9-in face. Four countersunk bolts were placed in each half of the tie section to attach T-shaped bars for making the pull tests. The halves of the tie section were then banded firmly together. The anti-splitting devices were applied and the bonds were removed. Slide 3 shows a test specimen after it had been pulled to failure in the Baldwin Testing Machine.

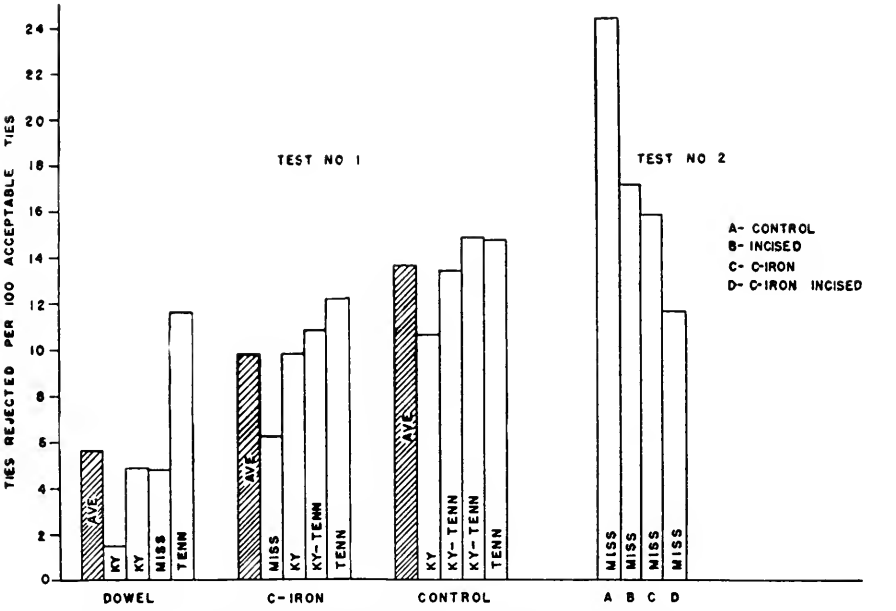
One group of ties was tested green and another seasoned in two months to 25 to 30 percent moisture content 6 in from the end before being tested. In all, three and four-flute dowels, flat C and S-irons, crinkled C and S-irons, 6-in Stronghold nails having annular grooves about two-thirds the length—driven from both sides of the tie—8-in Stronghold nails driven from one side, and gang nails (galvanized steel plates punched to form numerous prongs) were tested.

The four 6-in Stronghold nails had less holding power than two 8-in Stronghold nails. The gang nail was difficult to apply on a rough surface. These were tested green only.

As can be seen in Slide 4, all of the devices had enough holding power to withstand the splitting stresses that we found in our strain gage tests. The holding power



Slide 4—Holding power of anti-splitting devices.



Slide 5—The effect of anti-splitting devices on splitting of ties during seasoning.

in green and seasoned ties was relatively the same for all except flat C and S-irons. Crinkled C and S-irons had a little less and dowels had a little more holding power when seasoned. Flat C and S-irons both lost a great deal of their holding power on seasoning. This is attributed to the shrinkage of the wood away from the iron to substantially reduce the friction of the wood on the iron. Crinkled irons still had point bearing at each crinkle even after the wood had shrunk. The three-flute dowels held a little better than the four-flute dowels in both green and seasoned wood.

Another pull test was conducted to determine the holding power per inch of imbedment of the device in the wood. In these tests the device was driven to various depths into the wood. The maximum depth was one-half the length of the device, since any split not crossing the center of the device will have less than half its length to do the holding on the short side. To make the pull test, the device was clamped directly in the test machine.

There was very close correlation between the results of the two methods and with similar work done by the Erie Railroad in 1938 and the Pennsylvania Railroad in 1947. The relationship of the holding power at several steps in the production and service life of the tie was studied using red oak, white oak and TC[2] ties.

The kind of device and species of wood had more bearing than whether the device was applied green or seasoned. White oak and some of the TC species had more holding power than that of red oak. Dowels had greater holding power than did end irons, but as was shown earlier, require more holding power. Corrosion weakened C and S-irons,

[2] Mixed hardwoods, but not including gum.

Slide 6—Flat C-irons working out of tie after five years of service.

often corroding them in two in 10 to 15 years where there was heavy brine. Corrosion also reduced the holding power of dowels somewhat, but none tested had less than 1000 lb pull per in, nor was any corroded sufficiently to cause the metal to fail. As long as there was sufficient metal to withstand the pull, 1½ in imbedment of any of the devices was sufficient to withstand the stresses as measured by the strain gages.

Slide 5. To study the amount of splitting which occurs during seasoning and to compare the effectiveness of various anti-splitting devices, seasoning tests were conducted in cooperation with collaborating railroads using oak ties grown in Kentucky, Tennessee and Mississippi. These tests demonstrated that all of the anti-splitting devices in general use today retard splitting during seasoning to some degree, and that no device is completely effective. In Test No. 1 it can readily be seen that the control group had the most ties rejected for splitting and dowels the least.

Test No. 2 demonstrates that, in addition to doing its job of aiding the penetration of creosote into the tie during treatment, incising also helps control splitting. Alone it was about as effective as C-irons, but it was most effective when used in conjunction with C-irons.

The greater tendency of some wood to split more than others has been known for a long time and is further exemplified here. The Mississippi ties in Test No. 1 were fully as good as the Kentucky or Tennessee ties, but those in Test No. 2 were greatly inferior.

Since the control ties, with 14 percent split rejects, had only 8 percent more rejects than the 6 percent rejects for doweled ties, on might question the advisability of applying any anti-splitting device. If the benefit were limited to that obtained during seasoning, out-of-face application would seem highly questionable. However, anyone walking any stretch of track which has been in service many years will see a great number

of ties split beyond the acceptable limits for a new tie. These ties must have split in track.

This will be true whether the ties have anti-splitting devices applied or not. The severity of this in-track splitting and its effect on the life of the tie can only be surmised. As yet, no reliable information on this is available. Service tests are in progress from which we eventually hope to find an answer. Too, a service test is underway to determine the effectiveness of selective application of dowels compared with out-of-face application. This, of course, required application of the anti-splitting devices after seasoning rather than when the ties were green. In all, we are cooperating with four railroads in conducting service tests. C-irons, S-irons, doweling and banding are being studied, for these appear at the present to be the most promising. Control ties having no device of any kind are also included.

Slide 6 shows what many of you here have seen time after time as you walked track. Flat end irons begin to work out of the tie in 3 to 5 years, start falling out in 5 to 8 years, and in 10 to 15 years a great many have fallen out. Crinkled irons with a mid-rib stay in place much better. The rib presses a groove in the wood which helps secure the iron in the end of the tie. In a test on crinkled S-irons with a mid-rib, very few had started to work out of the tie in more than 10 years of service.

In evaluating the use of anti-splitting devices, one must know the annual cost of a tie in track in order to be able to calculate the number of years that the life of the tie must be extended to make its application profitable.

Using the AREA formula for calculating the annual cost of a 30-year tie based on 4 percent compound interest on the initial in-track cost of the tie, a $7.00 tie would cost 40 cents per year. Doweling costs, which run about 35 to 40 cents per tie for 100 percent application, would be covered by increasing the average life of a $7.00 tie by one year. Two years' increase would show a saving. C or S-irons, which cost about 20 cents per tie, would show a saving with a one year increase in tie life. However, if doweling gives one or more additional years over that for C or S-irons, it makes the greater saving.

Any of you who have attempted to accurately determine the average life of a group of ties knows how difficult that is. It is almost impossible to determine the average life to greater accuracy than one year increments, and extremely difficult to determine within one year. This makes the job of differentiating between one device and other equally difficult if there is not a marked difference between their performance.

In view of the fact that an increase in tie life of only one year will pay for the most expensive device commonly used today, it would appear to be a good gamble to use anti-splitting devices. Time alone will tell. It will take several years to get a clear indication from the tests now underway as to which device and which type of application would be most profitable. [Applause]

Assignment 9—Means for Effecting Greater Utilization of Timberland Growth Available for Cross-Tie Production.

CHAIRMAN FUDGE: The report on Assignment 9 will be presented by subcommittee chairman W. R. Jacobson, engineer timber inspection and treatment, Soo Line. This is the final report on this assignment.

W. R. JACOBSON: Mr President, members, and guests:

The report on Assignment 9 is presented as a final report. This has been quite a provocative subject and has elicited considerable, and I might say, at times, heated discussion. In fact, I believe views were as varied and as far apart as the species of

woods under discussion.

To prepare a report that had approval of the entire committee has been somewhat difficult. However, in connection with this report, the following should be borne in mind:

1. All railroads should have a complete knowledge of species native to their right-of-way and their procurement territory.

2. The technical and economic aspects of each species should be determined.

3. Use to the fullest extent all species to assist in maintaining the proper balance of the growing stock in the forests.

4. Investigate the newest methods for seasoning and treating.

This report is submitted as information.

PRESIDENT MEYERS: Thank you, Mr. Jacobson. It will be so received.

CHAIRMAN FUDGE: Mr. President, this concludes the report of Committee 3.

PRESIDENT MEYERS: Thank you, Mr. Fudge. It is very apparent that you people are still making progress in your studies on the very important subject of ties. It is important because it is one of the biggest costs to the railroads. Thank you, Mr. Magee, and Mr. Sutcliffe, for your contributions.

We know that the AAR research staff has been invaluable to you in your studies. I certainly hope that you can continue to work together as you have in the past.

Your committee is now excused with the thanks of the Association. The meeting is now adjourned until tomorrow morning.

[The meeting recessed at 5:30 o'clock.]

Morning Session—March 11, 1959

[The meeting convened at 9 am, President Meyers presiding.]

PRESIDENT MEYERS: Will the meeting please come to order.

This is the last of the technical sessions of our 1959 Annual Meeting, and with four of our committees yet to be heard from, at least three of which have lengthy presentations, it is important that we get started promptly and keep moving.

Discussion on Continuous Welded Rail

[For report see pp. 633–653.]

[President Meyers presiding.]

PRESIDENT MEYERS: Our first committee to report this morning is our Special Committee on Continuous Welded Rail, the acting chairman of which is C. E. Weller, assistant engineer maintenance of way, Illinois Central Railroad. Mr. Weller, I ask now that you proceed with your committee report.

ACTING CHAIRMAN C. E. WELLER: Mr. President, members and guests of the Association:

Our committee report is found in the February 1959 issue of the Bulletin, Vol. 60, No. 549.

I shall deliberately refrain from any remarks so that we can have more time for discussion at the end.

Assignment 2—Laying.

E. J. Brown, chief engineer, Burlington Lines, will present the report of the Subcommittee on Laying. Mr. Brown.

E. J. BROWN: Mr. President, members and guests: This report contains two significant facts. A review of the tabulation by years of continuous welded rail from 1933 to 1958, incl., reveals that, starting in 1955, there has been a definite increase in the

mileage of continuous welded rail. Of the total of 2191.80 miles, 1,738.29 miles were laid in the last four years.

In the early years of continuous welded rail, there was some apprehension about handling long strings of rail which were released through relay or were distributed and for one reason or another needed to be loaded and transported to another location. This report describes a specific instance on the Great Northern Railway wherein this problem was economically solved.

PRESIDENT MEYERS: Thank you, Mr. Brown.

Assignment 5—Economics.

ACTING CHAIRMAN WELLER: W. J. Cruse, engineer maintenance of way, Great Northern, will present the report of the Subcommittee on Economics. Mr. Cruse.

W. J. CRUSE: Mr. President, members and guests:

In 1958 a questionnaire was sent to various railroads requesting cost data comparing welded with jointed track. Replies are tabulated in Table 1 and Table 2, pages 638 and 639, Bulletin 549.

Of the 11 roads reporting complete cost data for rail in place, 4 roads show welded rail more expensive than jointed rail, 4 show no significant difference and 3 show welded rail, less expensive than jointed rail. The average cost for welded rail in place was $40,099 per track mile and for jointed rail in place $39,824 per track mile. Thus the difference in average cost per mile was $275, or less than 1 percent. This is slightly more than $1 per weld, assuming about 260 welds per mile of track.

In 1957 a similar economic study was made which showed the average cost per weld to be $14.80 for work done in the years 1948 to 1955; this may be compared to $12.51 which is the average cost per weld shown in Table 1 of this report for work done in the years 1953 through 1958.

It is evident that economies are being found in both welding and laying of welded rail as the roads gain experience.

Also of interest is the low figure on cost per weld submitted by the Santa Fe based on welding done in a new company owned plant acquired in 1958. This figure includes amortization of investment, plant upkeep and expense and all welding costs.

Of particular interest in Table 2 is the estimated average annual savings on maintenance with welded rail of $568 per mile. Also, estimated average life of welded rail in track is 32.3 years as compared to 24.4 years estimated average life of rail in jointed track.

PRESIDENT MEYERS: Thank you, Mr. Cruse.

ACTING CHAIRMAN WELLER: In addition the Subcommittee on Economics presents as information a special report on welding rails at or in the vicinity of rail mills. This is a joint report with Committee 4—Rail.

We also have a special report on field tests on continuous welded rail on the Great Northern Railway. The report will be presented by G. M. Magee.

Field Tests on Continuous Welded Rail on Great Northern Railway

By G. M. Magee
Director of Engineering Research, AAR

These tests were conducted in cooperation with the Great Northern Railway during the summer of 1958 with three objectives. One was to determine whether accumulative stresses are developed in continuous welded rail in service due to creepage forces. Another was to determine whether high buckling forces are produced in continuous welded rail ahead of a heavily braked train. The third was to determine whether jackknifing action of diesel units might produce buckling in continuous welded rail in hot weather.

Two locations were selected on the Great Northern not far from Fargo, N. Dak., for the tests. One was near Casselton on gravel ballast and the other near Nolan on crushed-rock ballast. A section of continuous welded rail, accessible to the test truck, was selected at both of these locations. At both ends of each 1500-ft length of welded rail, a short rail with two joints had been provided when the rail was laid in accordance with current Great Northern practice. To determine whether or not accumulated forces were developed in the rail due to creepage, reference points for a Berry strain gage were established to measure the longitudinal stress in the rail web at intervals throughout the length of each test section. A complete series of readings was taken both at Nolan and at Casselton on a hot, clear day. Following this the short rails were removed at each end of each welded section, the rail anchors were removed, the track spikes were lifted and the rail was supported on short rollers placed between the rail base and the tie plate seats on two ties per rail length. This permitted the rail to expand to its natural length at that temperature with little restraint from rail anchors and tie plates. A set of Berry gage readings taken with this condition gave the zero stress or base level of measurement from which the temperature stress could be determined for any other rail temperature. These two series of readings did not indicate any build up of stress in the welded rail from creepage forces, but only what would be expected from the temperature effects.

In February two other series of readings were taken at these locations at night at low rail temperatures, once when it was approximately 0 deg and again when it was 15 to 20 deg below zero. These readings have given additional data on the amount of joint restraint that is transmitted at each end from the rail joints and on the amount that rail anchors contribute to restraining end movement and joint gap openings at the ends of the continuous welded rail stretches.

For determining the buckling forces in the rail due to braking action, electrical strain gages were placed longitudinally on each side of the rail web at three locations spaced approximately 120 ft apart at Casselton and 80 ft apart at Nolan. A special test train was provided, consisting of diesel units and hopper cars loaded with ballast to give a total weight of 5000 gross tons. At both locations the train was heavily braked from speeds up to 60 mph as it approached the strain gages and the longitudinal or buckling force measured in the rail ahead of the train with the Association's electronic strain gage equipment. The maximum compressive force found at Casselton was 12,800 lb, equivalent to a stress of about 1000 psi and at Nolan 16,200 lb, equivalent to a stress of about 1500 psi. These buckling forces due to braking are quite low and would not be expected to cause buckling of track with continuous welded rail.

In making the jackknifing tests, the Association's special roller bearing tie plates were used to measure the lateral forces, and tests were made with diesel units pushing

against the loaded cars and other diesel units at the head end with dynamic braking. With regular type couplers having no alinement control, quite high lateral forces were developed due to jackknifing but no sun kink occurred even though the tests were conducted on a very hot day. In addition, the bending stresses were measured in the rail base and combining these stresses with the maximum stresses developed during jackknifing action and what might be anticipated from a temperature of 40 below zero gave a maximum combined tensile stress of 50,400 psi, which is well within the yield strength of 70,000 psi for rail steel.

A translation is now being obtained of tests conducted on the Japanese National Railways in which the rail was artificially heated until buckling occurred. Consideration is being given to conducting similar tests this summer in order to derive more information on just what buckling forces can be tolerated in continuous welded rail without the likelihood of the track buckling.

PRESIDENT MEYERS. Thank you, Mr. Magee.

ACTING CHAIRMAN WELLER: C. J. Geyer, retired vice president, construction and maintenance, Chesapeake & Ohio, and past president of the Association, has requested an opportunity to present some comments. I would like to invite Mr. Geyer to come to the speaker's table. Mr. Geyer.

C J. GEYER: Mr. President, Mr. Chairman, gentlemen of the Special Committee, members:

I appreciate the invitation of Mr. Weller to come up here on the platform and advance a criticism against the reports of his committee. It shows the courtesy of this committee and the Association and good fellowship.

For the past 23 years, this Association has received reports on continuous welded rail. In the past few years the committee has presented estimates of savings by the use of welded rail over jointed rail. In my opinion these estimates are not supported by enough factual data to justify their acceptance by the Association even as information.

In order to support my opinion on this subject, I have reviewed the reports and discussions in our Proceedings. I would like to give you a brief review on the high spots of these reports.

In 1936 the Committee on "Rail Longer Than 39 Ft" reported that the Delaware & Hudson Railroad was a pioneer in the use of continuous welded rail.

In 1937 the subject was assigned to the Rail committee.

Between 1937 and 1950 incl., a subcommittee of the Rail committee studied and reported on this subject.

It is unnecessary here to refer to those reports for the reasons I will show later.

In 1951 this assignment was withdrawn from the Rail committee and given to a Special Committee on Continuous Welded Rail.

The new committee reported that it contemplated a "cradle to grave study" and had divided the subject into five parts, i.e., Fabrication, Laying, Fastenings, Maintenance and Economics. Note there is no provision for study of "Disposal of Released Welded Rail." This is the "grave" part of the subject and very important in the economy.

I would like to add right here that the new rail laid by the railroads in the United States comprises approximately 1½ percent of the total rail mileage. The rail released by that 1½ percent is used to maintain the other 98½ percent. The No. 1 relay rail is used to patch our high-speed main line. Our No. 2 relay rail is used for secondary lines and the No. 3 for sidings, yards and industrial tracks.

It is important that we know the method and cost of getting this relay rail if it is all welded when released. I think that is the real economics in this whole problem.

In 1952 all of the subcommittees gave a report as information. I quote from the subcommittee's report on economics as follows:

"Most of the information carried over from the old committee cannot be used. Most of it is based on installations on the Delaware & Hudson Railroad. The Committee does not consider the Delaware & Hudson is a typical railroad and the information gathered on it is not applicable to other railroads. The Delaware & Hudson is a short railroad with very heavy traffic, grades and curves—the kind of railroad that wears its rail out quickly. It may be the Committee will recommend that welded rail is not economical for that kind of railroad."

So the new committee believed the information gathered on earlier installations could not be used in the new studies and that it must get new and better information.

So the new committee started its "cradle to grave" study by throwing 14 years work "out the window" and welded rail installations going back to 1933. It kicked the baby out of the cradle by reading the Delaware & Hudson "out of the party" and by inference, those railroads with similar characteristics through the Appalachian mountains like the Pennsylvania, Baltimore & Ohio, Norfolk & Western, Chesapeake & Ohio and others.

In 1953 the Committee reported savings for 131-lb and heavier welded rail as $671 per mile per year over the jointed rail. This was two years after they had thrown their own information away and said they would get new and better information.

This estimated saving was the average estimate of six chief engineers. Very little welded rail or the jointed rail with which it was compared had reached the end of its service life. The life of welded rail was assumed to average 26 years and jointed rail 19 years.

In 1953 the first welded rail ever laid was only 20 years old, if still in track. That was on the Delaware & Hudson.

Therefore, the only factual data for these estimates was the first cost of rail in place. This cost was reported to be $3,872 per mile more for welded rail than jointed rail. All other costs were assumed or at least based on cost of welded rail maintenance in its first few years of service life.

There was little information on the disposal of released welded rail; however, the committee reported it would cost $1,200 per mile more to relay welded rail than for jointed rail.

The estimated savings for 112 and 115-lb rail was arrived at by the same method except only three chief engineers made the estimates.

Since the report of 1953, there has been nothing of consequence in the general picture except the chief engineers reporting in 1953 revised their saving estimates. So in 1957, the Committee reported the saving by use of welded rail was $981 per mile per year. I note in this year's report it's now over $1000 savings per year for welded rail over jointed rail.

In my opinion the method employed to arrive at these estimates is too far fetched to justify a business risk, particularly in view of the heavy additional investment required in first costs.

I suggest the following method of approach to get the facts on this assignment:

Dig up all the information possible on every installation of welded rail that has been laid. Put this information in tabulation form. I suggest the following columns. 1—Name of railroad. 2—Location and length of welded section. 3—Type of weld. 4—

Weight of rail. 5—Degrees of central angle and rise and fall in feet within the limits of the welded section. 6—Accumulated tonnage carried. 7—Accumulated maintenance hours track labor. 8—Date Laid. 9—Date removed. 10—Weld failures. 11—Rail failures. Add footnote showing disposal by feet of welded rail released. And I think we should also have a column for the maximum allowable speed.

For each item of welded rail, list on another table similar information on jointed rail with conditions as nearly alike as possible to its counterpart in welded rail.

I believe that such tables prepared right now will show enough years of service life to indicate a fairly reliable comparative trend, and the information will grow more accurate and valuable with each year.

PRESIDENT MEYERS: Thank you, Mr. Geyer.

ACTING CHAIRMAN WELLER: Thank you, Mr. Geyer for your comments. I assure you that the committee at its next business meeting will discuss your remarks. Several items are of interest and will be of help to us.

I would like to make a few comments. First of all, the reports as presented by your committee have been presented as information. They were based on the best information and facts available to us at the time. Now, as Mr. Geyer pointed out, the report in 1953 was based on information received from a few railroads. The report on economics as presented this morning, however, was based on information that we received from 20 railroads. I think the recommendations Mr. Geyer made on the information that should be shown in table form is very good. I think that most of these items are shown in the two tables, Tables 1 and 2 on pages 638 and 639. They are shown, of course, only for welded rail. We have not shown this information for comparable jointed track.

We all must agree that the assignment is not completed. There is progress being made. There are changes being made almost every day in welded rail. Your committee has a lot of work ahead of it, and certainly many new subjects to study. The brief report made this morning on picking up welded rail on the Great Northern is just the first of many interesting reports that we can and will make.

The Delaware & Hudson information is a part of our records. I do not feel that the method of welding nor the costs incurred by the D&H back in 1933 is applicable and should be taken into our averages for welded rail today, and the averages that are given in our reports do not include the costs of welding on the D&H.

We realize that some of the methods that we use for estimating were not based on case history. However, they were based on the estimates furnished by those roads which have had experience with continuous welded rail.

Now, one of our future assignments must be that we will revise these estimates as the roads gain more experience with their welded rail, and finally, we must change these estimates to actual cost figures when they are available. Personally, I am proud of the reports and the work that your committee has done. I am happy to have been associated with it. Do we have any comments from the floor?

Mr. Blair, would you care to come up here please?

T. A. BLAIR: Mr. President, Mr. Chairman and gentlemen:

Sometimes I think Charlie Geyer just tries to agitate me. [Laughter] I am appearing here this moment as a retired chief engineer of the Santa Fe Railway, but during the time that I was on the job, I did furnish the figures for the Santa Fe that Charlie criticises and says may be a trap for management. So I want to go back to this year's report and explain the details of the Santa Fe figures.

It's going to take a little time. I hope this doesn't start a reaction where every

chief engineer will do the same thing. Maybe I can cover it in my extended remarks here so that it might not be necessary for other chief engineers to defend themselves.

I point to that one statement in which he infers that these figures are not even estimates, that they are just something we took out of our heads. That's not true. Turning to the Santa Fe figures in Table 1, we show data for a 10-mile test, installed in 1958. We show a comparison of the cost of the welded rail in place for that 10 miles as compared with jointed rail. We come up with a saving of $1193 per mile in favor of welded rail.

I am not going into all the history of that.

The first welded rail that we laid cost us materially more than did jointed track, but because our railroad lays enough rail so that it could justify the purchase and operation by company forces of a welding machine, we show a saving in the over-all investment of $1193 for this 10-mile test section.

That isn't the end. The cost of welds on the Santa Fe is going down every month, and the saving in investment is going to increase over the years rather than decrease.

Now for Table 2, which is the table covering the oldest stretch of welded rail reported on by these companies, the Santa Fe reports on a 5-mile test section installed in 1947. That 5-mile test was placed in a double-track main line where the tonnages eastbound and westbound are even for all practical purposes. One track was laid with 132-lb jointed rail, the other track laid with continuous welded rail.

To gather statistics we checked the section foreman's time book which shows the details of his work and whether he worked on the eastbound or the west bound track. So, the section foreman, the roadmaster, the practical people on the ground, determined these statistics.

Additionally, we had welded rail on an adjoining section of five miles for which we kept the information, and it checks very closely with the other. That isn't an estimate. It's the best that a human being can do to get facts.

Now the actual fact is that over a 10-year period we averaged a saving of $354 per mile per year in section maintenance.

Now, we have to do some estimating. An engineer wouldn't be worth a damn if he didn't estimate.

We gave these figures to our management, and I want to say that our management, after going over all of them, accepted them. They have installed over a thousand miles of welded rail. They have gotten the benefits of cheaper investment, of a better railroad, and better riding track. About that one statement of Charlie's: I want to be sure that nobody goes home with that and says there are not figures available that justify management looking into this matter to get some of the benefits.

Now I do get in a realm where Charlie has me dead to rights. We have 10 years' history with these comparative sections of jointed and welded rail. By observing the condition of that rail, we estimate—and I don't think that is a guess—we estimate how long the welded rail will be in place and how long the jointed will be in place, and for the Santa Fe our estimate is superconservative. The welded rail is going to be in there, I know, much longer than the figures that we used.

During my lifetime on the Santa Fe, I would say that 5 percent of the rail we relaid came out for rail wear. I know it's no more than 5 percent. The remaining 95 percent came out due to the fact that we had joints in that rail. It was rail and joint wear that in the end caused us to change that rail out, and with that in mind when we say that the welded rail will be in service 30 years and the jointed 25 years, we are being superconservative. I know that the welded rail will be in there much longer.

Now as for surfacing: They are now ready to surface the track with jointed rail but not the track with welded rail, so we know the welded-rail track is going to have a longer time cycle. We predict that the welded will go 12 years where the jointed goes 10 without resurfacing. There again we are on the conservative side.

In stating to our management what I thought the prospects of welded rail would be, I always used the savings in section maintenance. That's definite. We saved that money, and it isn't chicken feed. Take a railroad with 8000 miles, when we get the rail all in welded—and now there is over 1000 miles on our railroad—we have a saving of $3 million, and to a western railroad $3 million is a lot of money, and we are after it.

Now on the investment side—and we will save more money in investment over the years—but assuming that we do just what was done in 1958, with this 8000 miles we will save $10 million dollars in investment over the years. That isn't chicken feed to our type of railroad.

In connection with estimating, what does management ask about our tests? The first thing, where is that test? Well, ours is at a location where we have maximum temperature extremes on our railroad. It's in a track that for our railroad would be considered average. Tonnage is about 20 million a year, which is light, probably, for most of you folks. Our maximum will run up around 45, and we get down as low as 15 in our rail relay territory, but this appeared to be an average.

All right, our folks say that's fine. Now you say we can save money. You want to lay 200 miles of welded rail this year. The first thing we want to know, where are you going to make those savings and how much are they going to be in actual manpower?

The actual savings have been more than the predicted savings on our railroad because there has been more manpower cut off than this $354 would indicate, and the reason for that is because in recent years the relays have been in our heavier tonnage territory and by estimating again from the comparisons in tonnage we have been able to cut off more manpower.

Further on estimating: 10 years ago we had a certain method of surfacing. That's no longer in existence. We have a better method, a cheaper method. We have to doctor these figures every year because we are not static, so again we have to estimate. I think that prudent management will take those figures from an engineer—that's all I know what we are around here for, is to give them those figures.

However, my concern is really this: I am out, and I would hate to have somebody succeeding me quote something I said last year because already it is out-of-date. You are just moving so fast. Even if you are going to have to estimate, don't pass up the opportunity to really study the benefits of continuous welded rail because you are going to hurt your management if you don't. That's my conviction, and I leave it with you young folks. There are some problems, but you are going to solve them, and you are going to make the railroads some money.

Thank you. [Applause]

PRESIDENT MEYERS: Thank you, Mr. Blair. We have run over a half hour already. It's not fair to the other committees to spend any more time on this. There have been two sides, and if there are any other thoughts on the matter, please write them and send them to the secretary, and he will refer them to the Continuous Welded rail committee.

We have to finish this report and get on with the rest.

Charlie, we just can't take any more time.

MR. GEYER: Thank you, Mr. President, for shutting me off. [Laughter]

PRESIDENT MEYERS: We appreciate your remarks, Mr. Geyer and Mr. Blair, very much.

ACTING CHAIRMAN WELLER: Your new chairman, F. L. Rees unfortunately is on leave of absence, and couldn't be here today. However, I would like to introduce the new vice chairman, assistant engineer maintenance of way and structures for the Southern Pacific, W. J. Jones. [Applause]

Mr. President, this concludes our report.

PRESIDENT MEYERS: Thank you, Mr. Weller.

These differences of opinion are really the life-blood of our Association. Most of it is threshed out in the committees. It is healthy to have a little of it on the floor. We can only permit so much, however, or we would have to add two or three days to our convention.

Mr. Weller, we appreciate your stepping back into harness as acting chairman and bringing these committee reports to this convention. We look forward to the return of Mr. Rees to the Santa Fe in May, when he can take over his responsibilities as chairman of your committee. In the meantime, we know that Mr. Jones, as your new vice chairman, will see that the committee gets reorganized and the work for the current year put under way.

Your committee is dismissed with the thanks of the Association.

Discussion on Rail

[For report see pp. 873–976.]

[President Meyers presiding.]

PRESIDENT MEYERS: The next committee to make a report is our important Committee 4—Rail, of which I am a member. The chairman is L. S. Crane, mechanical research engineer, Southern Railway System, Washington. I could say quite a little bit about the work of this committee, but I do not want to take the time, so Mr. Crane, you will please proceed.

CHAIRMAN L. S. CRANE: Mr. President, members and guests: The report of Committee 4 begins on page 873 of Bulletin 549.

Because of the shortness of time, I want to make only a couple of remarks. We lost a large number of our committee last year through resignations and retirements. There are two of them I wish to pay tribute to. One of them is Tom Blair who has just been up here. I think what he said to you indicates the type of man he is. He is a clear thinker. He is a fighter. He has ably chairmanned several of our subcommittees during many years, and in his resignation we will lose a valuable member. We hope that he will come to our meetings and give us his valuable advice and counsel.

We also are losing Walter Leaf, research physicist, Denver & Rio Grande Western, who is transferring his membership from Committee 4—Rail to Committee 5—Track. I cannot let this opportunity pass without paying a special tribute to Mr. Leaf whose original research work in the field of joint bars and rails has contributed much to the work of our committee.

Assignment 1—Revision of Manual.

CHAIRMAN CRANE: W. J. Cruse, engineer of maintenance of way, Great Northern, will present the report on Assignment 1. Mr. Cruse.

W. J. CRUSE: Mr. President, members and guests: This is a report on Assignment 1—Revision of Manual.

[Mr. Cruse read the Manual changes pertaining to Rail Record Forms 402-A—

Reports of Rail Failures in Main Track, and 402–L—Annual Report of Progressive Type Head Failures in Rail of All Ages Made by All Processes, printed on pages 875–877 of Bulletin 549, same pages these Proceedings.]

MR. CRUSE: I move that these recommendations be adopted.

[The motion was duly seconded, was put to a vote and carried.]

MR. CRUSE: On page 4–1–13, delete Fig. 8—Recommended Head Easement for Joint Bars, substituting therefor the new drawing presented on page 875 of Bulletin 549. (Same page these Proceedings). I so move.

[The motion was duly seconded, was put to a vote, and carried.]

PRESIDENT MEYERS: Thank you, Mr. Cruse.

CHAIRMAN CRANE: It is now my pleasure to introduce to you the feature speaker on our program. He is research professor of mechanics and director of experimental stress analysis, Illinois Institute of Technology. He is an acknowledged authority in his field. It was my pleasure at a meeting of our Association several years ago to introduce this man to you, and at this time I know of no better way of introducing him than to paraphrase the remarks I made then.

It has been said of the man that is well versed in the subject that he is handling, that he knows the book. Gentlemen, Dr. Frocht wrote the book. Dr. Frocht.

Further Three-Dimensional Photoelastic Studies of Stresses in Rail Head Due to Wheel Contact Pressure

By Dr. M. M. Frocht

Research Professor of Mechanics, Director of Experimental Stress Analysis, Illinois Institute of Technology

Mr. President, Mr. Crane, gentlemen:

May I first of all thank you for your very kind introduction. I am not quite sure just what I should do in the few minutes that I have at my disposal, for several reasons—at least two. First, because a report on this study has already been prepared and distributed. It would be nice to assume that a good many of you have at least seen it and looked through the figures and the results. The second point is that I understand you are running overtime, so it behooves me to be brief. Therefore, I am going to omit a good many details of the method of procedure and make just a few general remarks about the nature of the problem and then show you some slides.

What is the problem, the general problem that we are dealing with? We are all familiar, both from our school studies and practical applications, with the problem of stress analysis in two dimensions. Until quite recently, that was about the only kind of stress analysis that was made. Quite recently, however, around 1951, we were able to perfect, or develop,—I shouldn't use perhaps the words "perfect" because it's still not perfect—a method which enables us to make complete three-dimensional stress studies, by the use of plastic models and the general method known as photoelasticity. So in a sense we are dealing here with something unprecedented in the history of stress analysis. I hope it can be some measure of consolation to members of the Association to feel that they have sponsored some pioneering work in this field.

Now, in what way does the three-dimensional stress analysis problem differ from the two-dimensional problem? In two-dimensional problems we know we have two principal stresses. We either calculate them, or measure them by use of strain gages, but in three-dimensional cases we have three principal stresses in the interior, and there are no reliable methods available to actually determine these three principal stresses

except in very simple cases. In very simple cases, or cases where the geometry is relatively simple, it can be done mathematically, but when the geometry, because of shapes and holes, becomes complicated, the mathematics become not only unwieldly for engineers, but also for mathematicians.

The photoelastic method we used in the study of the problem at hand actually determines the principal stresses in the interior, but here we have a difficulty that we do not have in two dimensions. In two dimensions the transition from the model to the prototype is not as difficult. The properties of materials, such as Poisson's ratio, do not enter the transition problem. However, in three-dimensional problems the transition is more difficult because the stresses in some way depend on Poisson's ratio even though it may not be a precise fact.

Now the main difficulties that arise in connection with the study really arise, not from the difficulties that we have in studying the stresses in the model of the rail head or the rail, but rather from the difficulties in the transition and difficulties of interpreting the meaning of the stresses in relation to shelly rail failures, or failures in general. There hasn't been enough work done on this subject. We don't know enough about the problems of the relation of stress to failure to be able to say: This means just exactly that. And so, first of all, I would like to present a few results, typical results, from the photoelastic study.

In the photoelastic study we made a transparent model of a rail head, a smaller model, two-thirds scale. In a previous study which I had the pleasure and the honor to present to you in 1953 we studied only the stresses in the transverse section of symmetry immediately under the center of the wheel.

This time our study was much more comprehensive; we not only studied the stresses in the same transverse plane as before, but what is more significant, we studied the stresses lengthwise along the rails, along three lines below the area of contact. May I now ask for the first slide; we will skip most of the others.

The first slide (see Fig. 4, page 960) shows the location of the lines that we investigated—the lines through points F, G, and H. The left corner is the gage corner of the rail, and the region G–H is the region where the maximum shear is generally developed in the rail.

Now I would like to skip all the slides and take the last two.

In this slide (See Fig. 10, page 967) we see the rectangular stress components along the line F–F. You see the three normal stresses—Sigma x, Sigma y, Sigma z, and three shears. In order to identify these stresses in relation to the rail, I would like to say that the x axis is the longitudinal axis of rail. The y axis is the vertical line, that is, the direction of the vertical load coming in the rail. The z axis is the axis which lies in the transverse plane. The three shears, Tau x, Tau y, and Tau z are associated with the normal stresses to give us the complete state of stress. This has never been done before so far as I know. We have never been able to determine experimentally the complete state of stress in the interior of a model.

These curves are quite typical for the other lines, G–G, H–H, and also for another load. This was done for a load of 78 lb, but we have also used a smaller load of 51 lb. The distribution is quite similar.

Slide (See Fig. 11, page 967). From the three rectangular stress components it is possible to find, and we have found, the three principal stresses Sigma 1, Sigma 2, and Sigma 3. For purposes of comparison I showed also the normal stress components, Sigma x, Sigma y, Sigma z. The shears are omitted here.

Now it is of interest to examine these curves and to see some rather striking things that one could not very well have anticipated without such a study.

First of all, you will notice that the three principal stresses are compressive immediately under the wheel, but as we go away from the wheel both to the right and to the left, all these compressive stresses become tensile. Even though the tensions are not very great, yet we develop a measure of tri-axiality. That, as you know, is a rather dangerous state of affairs in connection with causes of failure, especially when one keeps an eye on the conditions of fatigue, because as the wheel moves along the rail, each point changes from a state of tri-axial tension to a state of tri-axial compression. This is the first striking thing we noticed when we made the study with the 51-lb load. That is the reason why we went to a higher load in order to bring out a little bit more clearly the tri-axiality.

The next, and perhaps the most significant result which becomes apparent from a study of these curves, is indicated by point M on Sigma 1. It is the topmost point in the positive branch of the curve. Sigma 1 is a principal stress. That means it acts on a plane on which there is no shear.

Now we notice that whereas all three principal stresses Sigma 1, Sigma 2, Sigma 3, are in general compressive except far away from the wheel, Sigma 1 becomes a tensile stress at a point roughly 0.2 X over L. You can see how large that point is, by comparing the value at M, which is 10, with the — 25 for Sigma y. It's roughly 40 to 50 percent of the maximum value of Sigma y.

Now what does this mean? This principal plane on which we have the stress, Sigma 1, with this rather large value of tension, becomes extremely significant because planes parallel to it but in different locations are subjected to compressive stresses as well as shears. That means then that in the interior of the rail we have planes which are not only subjected to the fluctuations of small tri-axial tensions to large compressions, but we have this extremely significant state of stress: we have planes with fluctuating stresses—stresses fluctuating from a value of 40 to 50 percent of Sigma y to the rather large compressive value, plus the effect of the associated shear.

Just what that will do to the life of the rail is at present difficult to say. The fluctuations in the normal stresses, plus the variations of the horizontal shears and in the maximum shears for a 30,000-lb load is shown in the last slide (see Table 1, page 955). This is a summary for three lines—line F–F, line G–G, line H–H. I would like to call your attention to the three bottom rows, range of Tau xy, range of Sigma p, and range of Tau max. For line F–F the range of Tau xy is ± 35,000 psi, G–G, ± 30,000 psi, and H–H ± 37,500. Range of Sigma p—what is Sigma p? It is the stress on the plane on which we have the maximum Sigma y. It's an oblique plane, and the range on this plane is from 33,000 psi to — 39,000 psi for line F–F; 36,000 psi to — 44,000 on line G–G and 23,400 psi to — 32,400 psi on line H–H.

Similarly, we have the range of the maximum shear, Tau max—from zero to 42,000 psi for line F–F; to 51,000 psi for line G–G and to 54,000 psi for line H–H.

May I call your attention to the following: When you look at these figures you should also keep in mind the endurance limits which have been established—which I believe are at present accepted for these conditions. For example, the endurance limit for completely fluctuating limits is only 33,000 psi. That should be compared with Sigma p. The endurance limit for completely fluctuating shears is ± 37,000 psi. That should be compared with Tau yz, and the endurance limit for the maximum shears is around 59,000 psi which is very close to the 54,000 shown for line H–H.

We have found these are typical results, and I wish I could say the problem is completely solved. However, that would be overstating the case considerably. While we solved one problem, its solution revealed the need for solving a half-dozen new ones that we didn't think of before, such as problems arising from the question of transition, questions of scale and questions of material of the model. Then the most important question, which will probably take a good many years to answer and which isn't a question strictly of stress analysis, has to do with the meaning of stresses in relation to failure. Here we must consider properties of materials established by a long series of fatigue tests, and that is a rather formidable task. Thank you very much. [Applause]

CHAIRMAN CRANE: Thank you very much Dr. Frocht.

Mr. President, that concludes the report of the committee.

PRESIDENT MEYERS: Thank you, Mr. Crane.

The Association is greatly indebted to you and to your committee for the large amount of work which it has carried forward during the post year. I hope members of the AREA will read and study all the rest of the reports in the Bulletin that the committee is not discussing this morning because of time limitations.

We appreciate also the cooperative efforts of Mr. Magee and his staff in the work of this committee. I want to give our thanks to Dr. Frocht for appearing before us this morning.

Your committee is now excused with the thanks of the Association. Keep up the good work. [Applause]

Discussion on Track

[For report see pp. 785–871.]

[President Meyers presiding.]

PRESIDENT MEYERS: We will now hear from our Committee 5—Track, the chairman of which is W. E. Cornell, engineer of track, Nickel Plate Road. Mr. Cornell, please proceed with your report.

CHAIRMAN W. E. CORNELL: Mr. President, members, and guests:

The report of Committee 5—Track, will be found in Bulletin 549, pages 785 to 871 incl.

Your committee's report today will cover 8 of our 11 assignments. Discussion and suggestions from the floor to guide our committee will be greatly appreciated.

Assignment 1—Revision of Manual.

CHAIRMAN CORNELL: Our first report today will be on Assignment 1—Revision of the Manual. Subcommittee Chairman G. R. Sproles, assistant chief engineer, Louisville & Nashville, has been detained on his own railroad, and the report today will be given by L. H. Jentoft, assistant chief engineer maintenance of way, Erie Railroad.

L. H. JENTOFT: Mr. President, Mr. Chairman, members, and guests of the Association:

Under Assignment 1, Revision of Manual, your committee submits the following recommendation, which is shown on pages 786 and 787 of Bulletin No 549:

[Mr. Jentoft then read in full the report as printed on the aforementioned pages, moving that the recommendations be adopted and published in the Manual.]

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 3—Plans for Switches, Frogs, Crossings, Spring and Slip-Switches, Collaborating with Signal Section, AAR.

CHAIRMAN CORNELL: The report on Assignment 3 will be given by M. J. Zeeman, engineer of track design, Santa Fe.

M. J. ZEEMAN: Your committee submits for your approval as recommended practice and publication in the Portfolio of Trackwork Plans (a part of the Manual) three plans, Nos. 791–59, 792A–59, and 792B–59, all relating to track gage and flangeway widths for operation of diesel and steam power on curved track. The portfolio now has this data for steam operation only, and the proposed three plans cover both steam and diesel power, for which reason the two plans for steam operation should be withdrawn.

Therefore, Mr. President, I move the adoption of Plans 791–59—Tables of Practical Gages and Flangeways for Curved Track, 792A–59—Graph Showing Minimum Gages and Flangeways for Curved Track (Diesel Locomotives), and 792B–59—Graph Showing Minimum Gages and Flangeways for Curved Track (Steam Locomotives), as recommended practice and publication in the Manual (Portfolio of Trackwork Plans) and the withdrawal of previous Plans 791–34, and 792–34.

[The motion was duly seconded, was put to a vote, and carried.]

MR. ZEEMAN: Your committee also recommends for your approval some revisions of Paragraph 33 of the Specifications for Special Trackwork, Appendix A, page 1. These proposed revisions result in slightly closer tolerances in frog and crossing gages and flangeways, which are thought to be desirable for diesel operation.

Therefore, Mr. President, I move the adoption as recommended practice and for publication in the Manual (portfolio of Trackwork Plans) the revisions of Paragraphs 33 (b), 33 (c), 33 (d), and 33 (h) of the Specifications for Special Trackwork, Appendix A, page 1, as described at bottom of page 787, and top of page 788, Bulletin 540.

[The motion was duly seconded, was put to a vote, and carried.]

MR. ZEEMAN: The next item we wish to submit for your approval is a revision of Art. 15—Spring Washers, Appendix A, of the portfolio. The proposed revision is to limit Art. 15 to cover spring washers for railroad crossings only, since this double-coil type of washer is not needed for turnout frogs or guard rails requiring 1¼-in and 1⅜-in diameter bolts.

Therefore, Mr. President, I move the adoption as recommended practice and for publication in the Manual (Portfolio of Trackwork plans) the proposed new Art. 15—Spring Washers, shown on pages 788 and 789 of the Bulletin, to supersede present Art. 15 shown on page 8, Appendix A, of the Portfolio. Also, to save time, I am including in this motion, approval to make four minor revisions, detailed on page 789, on pages 3, 4, 6, and 7 of Appendix A.

[The motion was duly seconded, was put to a vote, and carried.]

MR. ZEEMAN: We are glad to report that a way has been found to take care of minor inconsistencies or errors on the plans in the portfolio. The method of handling this matter is considered to be editorial, and as such does not require convention approval. We took this subject up with Mr. Howard, executive secretary, who suggested that the procedure for handling these minor revisions be described as part of the "Foreward" on page 1 of the Table of Contents. Not only did Mr. Howard make the suggestion, but he also wrote the new "Foreward," which describes how these minor revisions will be handled in a new "Errata Section" at the end of the Table of Contents. We wish to express our appreciation to Mr. Howard for his valuable assistance.

Your committee finds that minor revisions are required on 32 plans, and it is proposed to show these revisions in the new errata section of the portfolio.

Therefore, Mr. President, I move the adoption of the revisions on the 32 plans beginning with plan 190–55 E–59 on page 791 and ending with Plan 783–55 E–59 on page 792, to be shown in the Errata Section of the Portfolio.

[The motion was duly seconded, was put to a vote, and carried.]

MR. ZEEMAN: The collaboration of our associate members, the manufacturers, in all of our work is gratefully acknowledged.

Your committee also submits a report prepared by the research staff of the Engineering division, AAR, being Appendix 3–a, Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill. Mr. President, this report is presented as information.

PRESIDENT MEYERS: It will be so received.

MR. ZEEMAN: This concludes the report on Assignment 3.

Assignment 4—Prevention of Damage Resulting From Brine Drippings on Track and Structures, Collaborating with Committee 15 and Mechanical Division, AAR.

CHAIRMAN CORNELL: Subcommittee Chairman W. E. Griffiths, chief engineer, Central Region, Canadian National Railways, had to return to Canada, and his report will be given by C. E. Peterson, assistant engineer, Santa Fe.

C. E. PETERSON: Mr. President, Mr. Chairman, members, and guests:

As indicated in the report published in Bulletin 549, which was prepared in collaboration with Committee 15 and the Mechanical Division of the AAR, the most important phase of this study is to develop a non-toxic brine inhibitor for use in refrigerator cars.

In this we have been helped by the Canadian National Railways, Department of Research, who have had a considerable measure of success in solving the problem and who have made all information developed by them available to us. It is true that there has been some lessening of the problem by reason of the increase in the number of refrigerator cars equipped with mechanical refrigeration, but the over-all problem is still serious and warrants the attention and help of all who are responsible for maintaining track and structures. It is therefore hoped that as many of you as possible will review this report.

Assignment 6—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear, Collaborating with Committee 3.

CHAIRMAN CORNELL: The report on Assignment 6 will be given by Subcommittee Chairman J. S. Parsons, chief engineer, Erie Railroad.

J. S. PARSONS: Assignment 6 concerns tests which are being conducted primarily for the purpose of determining the effectiveness and economy of various types of hold-down fastenings, tie pads, etc., as related to tie life and the frequency of regaging and readzing of curves. In other words, we are trying to determine the most economical and effective methods for extending the service life of ties by reducing plate cutting and the frequency of regaging and readzing curves by the use of special hold-down fastenings, tie coatings, tie pads, etc.

Our report this year is still in the nature of a progress report presented as information, covering service test installations on the Louisville & Nashville Railroad near London and East Bernstadt, Ky. The report covers the 11th annual inspection of the

service tests on this road which is cooperating with this committee and the AAR research staff under the direction of H. E. Durham, research engineer track.

During 1958 new test sections were installed as follows: (1) Bird 5-ply coated tie pads and Bernuth, Lembcke Company, Inc., gage lock spikes and tie plate lock spikes were applied to three 39-ft rail lengths on the 5-deg 36-min curve in the northward main track 0.5 mile north of East Bernstadt. The existing creosoted oak ties and 13-in double-shoulder tie plates were used. (2) Bird 5-ply coated pads were installed on 48 new ties in the 5-deg curve at East Bernstadt on August 26, 1958, in replacement of the Achuff sisal fiber pads. (3) Railroad Rubber Products, Inc., 7- by 9¼ in double-shoulder canted rubber tie plates were installed during August on 24 new creosoted oak ties. (4) Tire-carcass double-coated pads manufactured by the Konvex Tie Pad Co. of East St. Louis, Ill., were installed during August in replacement of Western Felt Works wool felt pads. (5) In Section 35 of the test, the north 30 alternate ties installed in July 1950 were recoated during August, using Koppers' No. 16 tie sealing compound spread over the top surface and covered with ¼-in stone chips. The subcommittee felt that recoating ½ the section should develop some data on the value of recoating part of the section for comparison with the ties not recoated.

Generally speaking, your committee has determined that expenditures for future savings, such as for extending the service life of ties, etc., without increasing the cost of a tie year, or preferably at a reduction in the cost of a tie year, should be made on a conservative basis.

Tests and information received from other railroads indicate that the greatest economies to be derived in the use of tie pads are in their installation on bridge decks and under insulated joints. As to hold-down fastenings, greater economy can be derived through their use on curves only.

In conclusion our service tests have developed that pads having a long-lasting seal are essential for obtaining maximum softwood tie life; that some of the hold-down fastenings are less effective in softwood ties than in hardwood, and that tie pads with special hold-down fastenings should have a longer service life than with cut spike construction.

The test is being continued in order to develop more definite conclusions, and a further detailed inspection will be made during May or June of this year and the findings published as our 1959 report.

PRESIDENT MEYERS: Thank you. Your report will be received as information.

Assignment 7—Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings.

CHAIRMAN CORNELL: The report on Assignment 7 will be given by R. G. Garland, roadmaster, Santa Fe.

R. G. GARLAND: Mr. President, gentlemen:

The final report of our eight-year service test of metal preservatives and methods of application in preventing frozen joints has been printed in the Bulletin as information.

We found that joints packed with Texaco 905 graphite grease and plastic H end plugs would give good protection, requiring no maintenance for more than seven years.

The spray method of lubricating joints at a cost of about 10 cents per joint was found to be effective in preserving and unfreezing joints. No-Ox-Id 100 shows good protection after three years of service.

During the last service period there were no stripped joints. This indicates that proper lubrication, together with proper anchorage, will solve the costly problem of stripped joints.

It is anticipated that we will be able to present to the next convention revisions in the Manual in the form of recommended practices for preventing frozen joints and stripped joints.

We are developing information as to preservatives and methods recommended when both jointed and welded rail are sprayed out-of-face to prevent or retard corrosion.

Should any of you have available in heavy brine territory a location where we can spray 78-ft rail or newly jointed and welded rail, we would appreciate hearing from you. We need about two miles of track for our proposed tests.

PRESIDENT MEYERS: Mr. Garland, I would suggest you get in touch with our Mr. Reid. We have miles and miles of 78-ft rails.

MR. GARLAND: Thank you.

Assignment 8—Laying Rail Tight With Frozen Joints.

CHAIRMAN CORNELL: The report on Assignment 8 will be given by J. B. Wilson, chief engineer, Georgia Railroad.

J. B. WILSON: Mr. President, members and guests. This year we are reporting on three test sections, all of which have different rail sections, joint bars and other characteristics.

The test section on the Louisville & Nashville near Chapel Hill, Tenn., has been under observation since October 1955 and the AAR staff has obtained three periodic sets of data. Over the last 0.94 year period, the middle bolts of the 132-lb, 6-hole headfree joints lost 40 percent of the applied tension. Intermediate and end bolt losses were 21 and 19 percent, respectively. This compares with 40, 24 and 31 percent losses on the middle intermediate and end bolts in 1957. On bolts tested for a two-year span, the losses increased to 60 percent on the middle bolts and 41 percent on the remaining bolts, making the average loss for the bolts in the two-year span 47 percent, or 23,500 lb remaining tension.

From an analysis of the joint gap pattern during the two year period of bolt maintenance, no adverse effect on the general maintenance was noted. It was found necessary during the second year of the test cycle to gas-weld 65 of the 211 joints on the plain-end rail. Inspection of the welds this past year revealed that the majority of them were performing well. Some of the joints which had not been built up continue to chip. Had the plain rail ends been carefully squared up and end milled with not too much undercut, chipping might have been greatly reduced if not eliminated.

The Erie Railroad test section near Crown Point, Ind., is laid with 115 RE rail with 6-hole long-toe bars and 1-in track bolts tightened to 35,000 lb tension. The south rail of the tight rail section was laid with rail temperature varying between 68 and 90 deg, or an average temperature of 79 deg. The north rail temperature, when laid, varied between 70 and 117 deg. On account of the high temperature of rails when laid, 167 of the 266 joints were open when track was checked December 11, 1957, when the rail temperature was 4 deg. When checked on September 22, 1958, with a rail temperature of 114 deg, 63 of the 266 joints were open, the average joint opening being 0.07 in for the 63 joints. This clearly shows that in order to have uniform tight rail in track, the rails must be laid at a medium temperature approximately half way between the coldest and hottest temperature of the section. This of course is practically impossible to accomplish.

The Bessemer & Lake Erie test section near Grove City, Pa., is laid with 140 RE rail. At the suggestion of the AAR staff, AREA 6-hole head-contact joints and 11/64 in carburized washers were used. Tension of 45,000 lb was applied to the 1⅛-in bolts.

Over a 0.72 year period, the middle bolts lost 43 percent of their tension and the intermediate and end bolts 29 and 33 percent, respectively. At the time rail was laid, joints were tight, but loss of bolt tension in the first month after laying was sufficient to permit considerable opening of joints with the relatively low temperatures that prevailed during the period. Winter gap readings obtained in February 1958 show a pattern similar to initial readings with an increase of 18 percent in the number of open gaps in the end hardened rail and 19 percent increase in the plain-end rail.

This coming year, your subcommittee together with the AAR staff will continue to study the three test sections and will give you further reports next year.

Assignment 10—Methods of Heat Treatment, Including Flame Hardening, of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding.

CHAIRMAN CORNELL: The report on Assignment 10 will be given by Subcommittee Chairman S. H. Poore, assistant engineer, Chesapeake & Ohio.

S. H. POORE: Gentlemen, this subject has been in progress for several years. It was started in 1954 to explore the value of heat treatment and flame hardening of frogs and switches and to also go into the matter of repair of these fixtures by welding.

The work has been progressed, using simulated crossing panels installed on the Milwaukee Road at Mannheim, Ill.

The reports to date seem to show that the panels fabricated of completely heat-treated carbon-steel rails can go longer than the flame-hardened rails before repair is necessary. It is worth noting that panels of used chrome-vanadium rail compare favorably with heat-treated panels (Proceedings, Vol. 57, page 954 and Vol. 58, page 1078).

When we come to repair by welding, it is practicable to deposit weld metal comparable to the original hardness by all methods of welding (page 868, Vol. 60, Proceedings) and in most cases the weld deposit is slightly harder than the original parent metal. The metal joint beneath the new deposit does not seem to be materially affected in the case of the flame-hardened items, although the original hardened volume of metal seems to be reduced to something comparable to ordinary carbon steel (Proceedings, Vol. 58, pages 914 through 924) immediately below the surface.

In the case of building up the completely heat-treated specimens: When weld metal is deposited by gas methods, the hardness imparted by the original heat treatment seems to be destroyed through substantially the entire rail head at the point of welding (Vol. 58, pages 925, 929, and 933.) When weld metal is deposited by electric methods on completely heat-treated specimens, their destruction of the heat treatment does not seem to penetrate as completely through the rail head as in the case of gas welding (Vol. 58, pages 927, 928, 930, 931, 932, 934, and 935.)

The used chrome-vanadium rail seems to hold its hardness very well without respect to the method used in depositing the weld metal.

PRESIDENT MEYERS: Thank you, Mr. Poore. Your report will be received as information.

Assignment 11—Economies to be Gained by the Railroads from the More Extensive Use of AREA Track Work Plans.

CHAIRMAN CORNELL: The report on Assignment 11 will be presented by Subcommittee Chairman W. R. Bjorklund, district engineer, Northern Pacific Railway.

W. R. BJORKLUND: Members and guests of AREA:

In studying our assignment we noted the multifarious designs used by the railroads for the construction of frogs, switches, and other track materials. Every number of frog,

and some fractions thereof, are being ordered from No. 5's to No. 16's and higher. The railroads, however, are consistent in not ordering No. 13 frogs.

Our assignment indicated the desire for a cost analysis. This proved impossible. Savings may be as low as 5 percent or higher than 30 percent.

The founders of AREA recognized the desirability of standardization. Old Proceedings show the heated discussions which took place 50 years ago. Those early reports indicated that each railroad representative had his own pet length of frog and switch. Invariably, the reports of the committee recommended a variety of lengths of switches and all numbers of frogs. The general statement was made that AREA was not attempting to standardize by issuing definite track-work plans; they were merely issuing guides to be used for making designs. Those same arguments and principles are present today.

Years ago, the railroads could afford to be individualistic. Under present highly competitive business conditions it behooves all of us to make our particular phase of the railroad industry operate at greatest efficiency and economy. There would be a tremendous saving had the standards of AREA been adopted many years ago and the number of frogs and switches been reduced to the minimum requirements for safety, speed, and riding comfort. Those three factors are the only arguments we can present for a particular design of track material. If we can get safety, speed, and riding comfort and be further blessed with greatest economy, then our mission as engineers for the railroads should have been fulfilled.

I should like to quote Mr. Herbert Hoover, who in 1923, as chairman of the National Committee on Standardization, stated: "The differences when they occur are frequently and perhaps generally of a minor character and altogether too often require only slight modification in the product. This practice can, of course, in some instances be defended, but in the writer's opinion in a very large number of cases, results in a higher cost to the purchaser without any corresponding gain in the quality of the material."

It is recognized that standards are not frozen or unchangeable. It can remain a standard only so long as it represents the best practice. In order to maintain the value of standards, revisions should be made by the same agencies which created them. Otherwise, there would be a return to the original chaotic conditions.

Your subcommittee has prepared a report generalizing the advantages by pointing out that the railroads of this country should and must standardize on track materials in the interest of over-all economy. In preparing our report we recommended that the AREA Trackwork Plans be modified to designate specific designs, including the elimination of alternates. The assignment of Subcommittee 11 dealing with economics may be considered final. The actual review of the Trackwork Plans and the recommendations for nationwide standards will be carried on by Subcommittee 3 of your Track committee.

This report is submitted as information.

PRESIDENT MEYERS: It will be so received.

CHAIRMAN CORNELL: Mr. President, members of the AREA, and guests:

This completes the reports on our assignments.

It is now my pleasure to introduce as a special feature a talk by one of the veteran members of our committee. Our speaker has been a member of our Association since 1929, a member of Committee 5 since 1934. He has served as chairman of Subcommittee 3—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, from 1951 to date.

His work as engineer of track design on the Santa Fe has kept him in such close contact with the design and development of frogs and switches that he has been able to carefully evaluate the trends and the urgent need for standardization. It is a pleasure to me at this time to introduce one of the most tireless workers of our committee, Martin J. Zeeman. Mr. Zeeman. [Applause]

Standardization of Turnouts—What Must be Done to Achieve it?

By M. J. Zeeman
Engineer of Track Design, Atchison, Topeka & Santa Fe Railway

Mr. President, Mr. Chairman, members and guests: Thank you, Mr. Cornell, for this nice introduction. I hope I don't disappoint you too much.

I consider it an honor and a privilege to address you on the subject of Standardization of Turnouts. This problem has been discussed by the Track Committee for the last few years without having reached a satisfactory solution, so I would like to present for your consideration some of my views. This is a highly controversial subject, and it is very difficult to reach agreement on any one plan, although I am certain that every one here knows that the result of agreement would be a substantial saving to the railroads in many ways, as pointed out in the report of Subcommittee 11. I do not believe that this matter can be tied up at this time in a complete package by any one individual to everyone's satisfaction, but if a few roads would take the lead, it is likely that others would follow gradually.

Probably one of the main reasons why turnout units have not as yet been standardized is due to the fact that it is economical for each road to replace or renew the parts or units in kind, thereby not adding to storehouse stock or causing confusion in the field. Since we are not compelled by any order from competent public authority to use a prescribed standard, the lack of standardization, therefore, seems to be a penalty of our system of free enterprise. It is also probable that company pride in their own plans has kept some roads from admitting the possible savings through standardization.

The AREA Trackwork Portfolio contains a large number of recommended plans, giving detailed information for 13 turnout numbers, with a multiplicity of plans for frogs and switches, with alternate complete designs as well as alternates for details. A "common" standard, which was, and is, the objective, could not be developed in committee work due solely to the differences of opinion of the engineers as to "which is best." Therefore, the alternate designs are the result. Also, we should not lose sight of the fact that there are a lot of railroads in this country, large and small, with greatly varying operating conditions as well as kinds and densities of traffic. Each railroad, large or small, can find in the present Portfolio a plan which suits its particular need.

Research, as well as individual ingenuity on the part of manufacturers and railroad engineers are constantly improving certain parts of the railroad track structure. When turnout material is standardized, adequate machinery should be set up to make improvements available with a minimum of delay, otherwise we may lose more by not being able to get the benefits of improvements than we gain by adhering to the standard. Therefore, possibly a certain time limit should be placed on an adopted standard, say 3 or 4 years, during which time no changes would be made, but some committee should investigate the suggested improvements so that the standard can be brought up to date at stated intervals. However, in case a major improvement is found, self-evident as to safety and economy, it should be made available sooner.

In the October 1958 issue of the AREA News, our President, Mr. Meyers, called attention to the need of standardization, not only of turnouts, but of rail sections, rail drilling and joint bars as well. The number of rail sections, different rail drillings and joint bar sections certainly complicates standardization of frogs and switches.

There is a strong feeling at the present time that the AREA should eliminate a lot of the alternates and that, in order to obtain the advantages of standardization, a minimum number of designs for frogs, switches and guard rails should be selected from the Portfolio to meet the traffic density and speeds generally required in turnout operation. There occasionally will be some special locations, which should be handled individually.

The job before us then is to select the particular turnouts to meet these requirements. To provide a basis on which to start work, I respectfully wish to submit the following plan for your consideration:

Designate four turnouts as standards for general use. These to be:

No. 8—for yard turnout

No. 12—main track, slow speed

No. 16—main track, intermediate speed

No. 20—main track, high speed

My main reason for including the No. 16 is that this turnout will be the "high speed" turnout for many roads not requiring No. 20 turnout speeds.

Now specifying the component parts of these four turnouts:

No. 8—13-ft 0-in curved switch with graduated risers. Two rigid frogs, one of which is bolted and the other solid manganese steel self guarded. Tee rail guard rails for the bolted frog. Permissible speed, based on 3-in unbalanced elevation, 20 mph.

No. 12—19-ft 6-in curved switch with graduated risers. Two frogs, one of which is rail-bound manganese and the other a spring rail frog, short spring rail type. Tee rail guard rails. Permissible speed, 29 mph.

No. 16—26-ft 0-in curved switch with graduated risers. One frog, being rail bound manganese. Tee rail guard rails. Permissible speed, 40 mph.

No. 20—39-ft 0-in curved switch with graduated risers. One frog, being rail bound manganese. Tee rail guard rails. Permissible speed, 50 mph.

It should be understood that the above applies to lateral turnouts only, since the Portfolio does not include equilateral turnouts

I believe it desirable now to give you the reasons for selecting these four turnouts and their parts.

Curved switches: It is obvious that movement through a turnout equipped with a switch curved substantially the same as the lead curve provides better riding than could possibly be obtained with a straight switch. The four turnouts recommended meet this condition. For a turnout movement, the curved point per detail 5100 on Plan 221–55, commonly known as Samson point, is definitely stronger than a straight point per detail 6100, although the latter is preferred for the straight point of the curved switch. All lengths of switch points, 13 ft, 19 ft 6 in, 26 ft and 39 ft are made from 39-ft rails without waste.

Besides providing practically uniform curvature from point of switch to toe of frog, curved switches for No. 8, 12 and 16 turnouts reduce the lead length considerably, but the lead of the No. 20 turnout with 39-ft curved points is about 4 ft greater than with 30-ft straight points. For the No. 8 turnout, the lead is 9 ft shorter with 13-ft curved

points than with 16-ft 6-in straight points; for No. 12 turnout the lead is about 9 ft shorter with 19-ft 6-in curved points than with 22-ft straight points and for the No. 16 turnout the lead is 13 ft shorter with 26-ft curved points than with 30-ft straight points. All of these items make for economy, in first cost as well as in maintenance, and the only additional cost, not incurred when straight switches are used, is for undercutting of the stock rail for the curved point.

Graduated risers: My choice for switches with graduated instead of uniform risers is largely determined by the distinct advantage and economy of being able to use hook twin tie plates. For each rail section, all turnout plate requirements are filled by using three lengths of twin plates, with two plates for each length, or a total of six different plates, for the four lengths of switches. Furthermore, these same plates are also used for all rigid frogs and at toe and heel ends of spring rail frogs. Another advantage is the flexibility in spacing of switch ties, which is particularly valuable where switch ties are already in place. Comparing this with the machined individual turnout plates required for switches with uniform risers, also for one rail section, the four lengths of switches require a total of 49 different plates. All of these plates are machined from 1¼-in thick stock, for a predetermined tie spacing, leaving ¾-in thickness under the rail base, which is the same thickness as the twin plates, hence the special machined plates are not any stronger, but cost a lot more and are not as flexible. Of course, the actual number of special turnout plates for each length of switch is determined by the size of the standard tie plates used.

Concerning switch plates: The plans for the curved switches in the Portfolio show that all gage plates and certain slide plates are equipped with adjustable rail braces. Standardization of switch plates is complicated due to the fact that practically every manufacturer has its own patented design of rail brace and the plates are made to fit that design. There is a notation on Plan 224–55 that the rail brace and plate shown are for illustration only, but the specifications on this plan may require revision because there are efficient braces on the market which do not conform to these specifications in that they are fastened with only one bolt. I think one important provision should be that bolt or bolts securing the brace are placed in such a manner that they can be replaced in track without having to remove the plate from the tie. It may be possible for the manufacturers and ourselves to get together and agree on one type of rail brace, which would permit us to standardize on the switch plates. If this cannot be done, we may have to be satisfied for the present by standardizing on the switches, switch rods and turnout plates and give further study to the switch plates.

Before leaving switches, I wish to mention that plans for the 13-ft and 19-ft 6-in switches (122–55 and 124–55), show the center line of the first switch rod located 12 in from the point for hand throw and 17 in from the point for interlocked switches. That means two different switch points. I think there should be one location for the clip of the first rod, making the point suitable for hand throw as well as interlocked switches, which can be done by spacing the switch ties to suit the method of operation.

So far I have not mentioned spring switches. This type of switch is certainly a source of economy in many locations. I believe that they should be adopted as a supplemental standard switch by modifying the 19-ft 6-in, 26-ft and 39-ft curved split switches in line with Plan 181–51.

Now referring to rail-bound manganese steel frogs: You may have noted that the Nos. 16 and 20 standard frogs would be of this type, also the No. 12 frog of the rigid type. The Portfolio contains two designs of rail-bound manganese frogs, one for 90 lb and heavier (Plan 600–55) and one for 112 lb and heavier (Plan 621–55). The 90-lb

design covers all angles from No. 4 to No. 20, and the 112 lb and heavier all angles from No. 6 to No. 20, so there are two designs for No. 6 to No. 20 for rails 112 lb and heavier. Plan 600–55 shows light sections which are, in my opinion, suitable only for lightweight rails, so I would confine this plan only to standard Nos. 12, 16 and 20 rigid frogs for rails less than 112 lb. Plan 621–55 calls for heavy sections; in fact, the side walls are so thick that there are possibly only a few railroads in the country with traffic heavy enough to justify this design. For this reason, in order to make this plan suitable for general use, I recommend to revise Plan 621–55 to call for walls 1¼ in thick instead of 2 in and 1⅝ in as now shown, and then use this plan for standard Nos. 12, 16 and 20 rigid frogs for rails 112 lb and over.

With reference to the No. 12 spring rail frog: The principal reason for selecting the short spring rail type frog is the fact that a much stronger joint is obtained at the toe end, which makes a better anchor against creeping of the loose spring wing rail. There also is an advantage in reducing the length of the loose spring rail in the main track.

Relative to guard rails: Considering all things, I believe the bolted tee-rail guard rail, on canted plates, may be slightly more advantageous than the one piece manganese steel guard rail. One characteristic of one-piece guard rails is that they are short, on account of the high cost of manganese. Another characteristic is that they are good for only one uniform predetermined switch tie spacing. This is somewhat of a handicap when switch ties are already in place, whereas the tee-rail guard rail has some flexibility in spacing of ties. Also, there is a greater tendency to spike kill switch ties with one piece guard rails because any flangeway adjustment must be made by changing the spikes.

Also in favor of the tee-rail guard rail is that it provides an outlet for short pieces of new rail, including No. 2, as well as second-hand rail. With the vast amount of short length rails, this is important. Tee-rail guard rails can be made long enough to protect the frog points and particularly in spring rail frogs where the loose spring rail should be protected from the toe joint to a point where the running rail head is standard width, to minimize wear due to lateral movement of the wheels. This last comment also applies to rigid frogs. At present, the only design of tee-rail guard rails, Plans 504–55, calls for flat plates. There was a plan, No. 503–40, which called for canted plates but this plan was suspended in 1942. In my opinion, guard rails should have plates with a canted rail seat, and I hope that the Track committee will look into this and, if consistent, submit a suitable plan for your consideration.

Times does not permit me to go into any more of the various details which would be used in the suggested standards, as alternates would be eliminated. Suffice it to say that, if you approve of the more important parts mentioned, I believe the details can be agreed upon without too much trouble.

How can we handle the plans for the turnouts recommended as standard? I do not believe that any plan should be removed from the Portfolio, but that one sheet can be added, this sheet to show all information basic to the recommended standards, with references to the detail plans. Then each of the plans of the various parts of the standards can be marked with some symbol or letter, to be shown on the new sheet of standards.

Of course, in case the Track committee should run out of work, it would be very helpful to make up four standard turnout plans, one for each of the four standards. We have heard considerable criticism about the great number of plans which have to be consulted in order to get data for a complete turnout, and if the Portfolio should contain a complete standard turnout plan, showing all of its component parts, including ties and their spacing, typical rail layout, etc., I am certain it would be very useful.

Last, but not least, is the question, "when can a road adopt a new standard?" Usually the answer is, when it adopts a new rail section. This, of course, is true, but I believe that a road could also do this without having to wait for changing to another rail section. No one at present knows just what the savings would be in case all roads would adopt a common standard, in the meanwhile, going at it piecemeal, not much benefit would accrue at first, but it would become greater as the use of the standard increased. By making a change from the road's present standard to the new standard for the same rail section would involve carrying in stock parts for two different types of material during the transition period, and this is costly and sometimes confusing. However, if we continue to make replacements of our present material in kind, we will perpetuate its use and never get a common standard.

Standardization of Turnouts—What Must Be Done to Achieve It? As stated before, we must have a plan or basis on which to start work. It is earnestly hoped that each of you who believes in standardization, will seriously analyze what has been suggested. There is no doubt in my mind that with your help it can be improved upon so that it may be more acceptable to the industry in general. Then, after the final plans have been agreed upon, there is still one more job to be done and that is to work towards the adoption of these plans by our own roads.

I thank you for your kind attention. [Applause]

CHAIRMAN CORNELL: Mr. Zeeman, I am pleased that our committee has had the privilege of hearing your report as a special feature, and I want to thank you for a job well done.

Mr. President, this completes the report of your committee and also completes my chairmanship. I have gotten much out of my work as chairman of Committee 5. I want to thank you and all the members of the Association who have given me the privilege to thus serve you. I want to especially thank Mr. Howard, the subcommittee chairmen and all members of Committee 5 for the expert help they have so generously devoted and given to forwarding our work. It really has been a pleasure to have worked with them.

It is my pleasure at this time to introduce your new committee chairman, Troy West, engineer of track, Union Railroad. Stand up, Mr. West, please, and your new vice chairman, S. H. Poore, assistant engineer, Chesapeake & Ohio. [Applause]

I wish Mr. West and Mr. Poore the greatest success possible in their new assignment, and I am sure that they are capable of doing a fine job for you. I want to thank all of you again.

PRESIDENT MEYERS: Mr. Cornell, I want to thank you for the wonderful reports you presented this morning, and the manufacturers and all of the others who have worked with you in making it possible. I also want to thank Mr. Zeeman, not only personally, but on behalf of the Association for doing some real thinking, which I am sure in time will result in considerable benefit to the entire railroad industry.

I would like to make a few comments here that don't necessarily apply alone to Committee 5. I have felt for some time that many of the recommended practices in our Manual are not necessarily the best that we have or that we know about. I think in too many cases they are the result of compromise in committees. I think if this Association is going to avoid the brand of not being progressive that our committees in many cases have to take a little bit diffffferent attitude towards these things, then should get all the facts, develop the best standard or practices possible, and then not

let a small minority compromise them because somebody's feelings might be hurt or because some roads may have pride in something they are doing. That is not the way progress is made in my opinion. I think we should all give that serious consideration.

I would like to talk quite a little bit here about what Mr. Zeeman said, but due to time, Mr. Geyer, I must cut myself off, and proceed with the program. [Laughter].

So, without further ado, we will dismiss your committee with the thanks of the Association, and welcome Troy West and Stewart Poore who I know will carry on the fine work of Mr. Cornell and his committee. [Applause]

Discussion on Roadway and Ballast

[For report see pp. 655–783.]

[President Meyers presiding.]

President Meyers: The next and final report of our technical committees is that of our Committee 1—Roadway and Ballast. The chairman of this committee, serving for his first year, is G. B. Harris, assistant engineer, Chesapeake & Ohio, Richmond, Va. Mr. Harris, you may now proceed.

Chairman G. B. Harris: Mr. President, members of the Association, ladies and gentlemen:

The report of Committee 1 will be found in Bulletin 549, beginning on page 655. You may have noticed it is a very voluminous one, in fact, the longest to be presented this year, and which may account for the fact that we are again on this tail end of the agenda here.

It may be the longest report, but I assure you it's not going to be as long as some of them. We are going to try to cut the time down as much as possible.

During the past year we lost one member by death and five for other reasons. Six guest members will become active members at the close of this convention.

Before proceeding with the presentation of our reports, I want to take this opportunity to express not only my personal sorrow, but also that of the whole committee at the passing of one of its valued members through death last year. Lloyd Dewaine Shelkey, assistant engineer, Bessemer & Lake Erie Railroad, was instantly killed in an automobile accident at the south end of his railroad. Mr. Shelkey began his railroad career with the engineering corps, Pennsylvania Railroad in 1934. In 1941 he entered service of the Bessemer & Lake Erie as assistant supervisor track. He held various positions with this road and at the time of his death was assistant engineer in the office of chief engineer. He had been a member of the Association and Committee 1 since 1949 and at the time of his death was chairman of Subcommittee 6—Roadway. A memoir in honor of Mr. Shelkey is included as part of our report.

This year your committee reports on 8 of its 11 assignments. We solicit your comments, suggestions or criticism of any of our reports that you may care to offer. We may not be able to answer all question you may have at this time, but in such a case we shall certainly attempt to find the answer for you.

We have three Manual recommendations which will be presented by the subcommittees involved instead of under Assignment 1—Revision of Manual.

Assignment 3—Natural Waterways: Prevention of Erosion.

Chairman Harris: The first report to be presented this morning is on Assignment 3. F. R. Naylor, assistant to chief engineer, Texas & Pacific Railway and chairman of Subcommittee 3, was unable to be here today. In his absence I will ask G. W. Becker, special engineer, drainage, Chicago, Rock Island & Pacific Railroad to present

the report. Mr. Naylor who is retiring from railroad service later this year is, as of the close of this convention, retiring as chairman of Subcommittee 3.

Mr. Becker will succeed him as chairman of that subcommittee.

G. W. BECKER: Mr. President, Mr. Chairman, members, and guests:

In 1955, your committee presented a report on the prevention of bank erosion in natural waterways of the alluvial type by the use of steel jetties. In 1957 a supplemental report was submitted covering various other types of stream bed and bank-protection installations.

Today we are presenting a report covering an additional method for preventing erosion, the results obtained under flood conditions from previously described installations and the effects of the floods on the various installations.

The report is submitted as information.

PRESIDENT MEYERS: Thank you. It will be so received.

Assignment 4—Conditions Requiring Headwalls, Wingwalls, Inverts, and Aprons, and Requisites Therefor.

CHAIRMAN HARRIS: The second report, that on Assignment 4, will be presented by G. D. Mayor, division engineer, Chesapeake & Ohio Railway, and subcommittee chairman.

G. D. MAYOR: Mr. President, Mr. Chairman, members, and guests:

Your committee has fulfilled its assignment by presenting a final report, which is in effect a symposium and condensation of replies received from 28 railroads.

The report, beginning on page 665 of Bulletin 549 is submitted as Manual Material. Mr. President, I move that this report be adopted and published in the Manual at the end of Part 4—Culverts, Chapter 1.

[The motion was duly seconded, was put to a vote, and carried.]

MR. MAYOR: Mr. President, it is recommended that this subject be discontinued.

PRESIDENT MEYERS: It will be so ordered.

Assignment 5—Specifications for Pipelines for Conveying Flammable and Non-Flammable Substances.

CHAIRMAN HARRIS: K. W. Schoeneberg, chief engineer, Akron, Canton & Youngstown Railway, chairman, Subcommittee 5, will give us a brief progress report on the activities of his subcommittee in connection with pipelines for conveying flammable and non-flammable substances. Mr. Schoeneberg.

K. W. SCHOENEBERG: Mr. President, Mr. Chairman, members, and guests:

Your subcommittee on Assignment 5 has submitted a report as found on page 668 of Bulletin 549 with reference to the progress being made in collaborating with the ASCE Committee on Pipeline Crossings of Highways and Railways, and also the progress being made in studies of the present Manual material on pipeline crossings and longitudinal occupancy with the view of revising same.

This report is submitted as information.

Assignment 6—Roadway-Formation and Protection: (a) Roadbed Stabilization; (b) Slope Protection by Use of Additives.

CHAIRMAN HARRIS: Due to the death of Mr. Shelkey, to which I referred earlier, the next report will be presented by F. N. Beighley, roadway engineer, St. Louis–San Francisco Railway. I might add that Mr. Beighley succeeded Mr. Shelkey as chairman of Subcommittee 6.

F. N. BEIGHLEY: Mr. President, Mr. Chairman, members, and guests:

Your committee reports this year on Assignment (a) Roadbed Stabilization, only. The report covers "Soil Engineering Problems on the Quebec North Shore & Labrador Railway." It was prepared by Professor K. B. Woods, head, School of Civil Engineering, Purdue University; R. W. J. Pryer, Soils Engineer, Quebec North Shore & Labrador Railway; and W. J. Eden, Division of Building Research, National Research Council, Canada. Later in our program one of the authors of the report will give us an illustrated talk about these problems and how they were solved.

The report is submitted as information.

Assignment 8—Fences.

CHAIRMAN HARRIS: The recommendations of Subcommittee 8—Fences, will be presented by the subcommittee chairman, L. J. Deno, division engineer, Chicago & Northwestern Railway. Mr. Deno.

L. J. DENO: Mr. President, members, and guests:

Your committee has considered and approved several revisions to the specifications for right-of-way fences, and the addition of illustrations of the four classes of recommended right-of-way fences.

Your committee recommends that the entire Specifications for Right-of-Way Fences, pages 1–6–10 to 1–6–14, incl., in the Manual, be reapproved with the revisions printed on pages 688 to 692, incl., of Bulletin 549.

Mr. President, I so move.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 9—Roadway Signs: (a) Reflectorized and Luminous Roadway Signs, Collaborating with Committees 5 and 9 and Signal Section AAR; (b) Developing Standard Close Clearance Warning Sign, Collaborating with Committee 28.

CHAIRMAN HARRIS: The chairman of Subcommittee 9, J. E. Chubb, freight traffic manager, Pennsylvania Railroad, who is also our vice chairman, was unable to be here today. In his absence I am going to ask L. H. Bond, assistant engineer, Illinois Central Railroad to briefly summarize the studies completed by the Armour Research Foundation on possible new nuclear light sources. Mr. Bond.

L. H. BOND: Mr. President, Mr. Chairman, members, and guests:

Under Assignment 9 (a) the Research Department of the AAR, at committee request, has sponsored a study on reflectorized and luminous signs through a research project to determine the feasibility of nuclear light sources. The work was performed at Armour Research Foundation and their final report appears in the Bulletin.

This report summarizes the work to date with recommendations for further investigations along the most promising lines developed in the present study.

For Assignment 9 (b), progress can be reported but no formal report should be made at this time.

Assignment 10—Ballast: (a) Tests; (c) Special Types of Ballast; (d) Specifications for Sub-Ballast.

CHAIRMAN HARRIS: R. H. Beeder, chief engineer system, Atchison, Topeka & Santa Fe Railway, and chairman of Subcommittee 10, will next advise us of the activities of his subcommittee during the past year, together with recommendations for revision of the Manual.

R. H. BEEDER: Mr. President, members, and guests:

Your committee reports this year on two of its projects under Assignment 10—Ballast.

The report on Assignment 10 (a)—Ballast Tests, is submitted as information and is the sixth report on the progress that started with the oscillator equipment and is now being carried forward with improved equipment consisting of an Amsler pulsator and hydraulic jacks. This equipment is being utilized for repeated-loading tests on ballast, and we expect to make a comprehensive report on these tests next year.

The report on Assignment 10 (c)—Special Types of Ballast, is submitted as information to cover the proposed program this year to treat approximately 30 track miles of ballast section with asphaltic materials under the sponsorship of your committee, the AAR Research Department and the Asphalt Institute. The special hopper car and asphalt distributor car were not completed early enough to make the applications before colder weather; therefore, the work will start the last of this month in California and move progressively eastward with test locations in seven states.

Your committee recommends revision of our Specifications for Prepared Stone, Slag and Gravel Ballast.

Gravel in many areas is produced from large oversize material in which substantially all particles are crushed and which is, therefore, essentially a crushed stone. In order to classify crushed gravel ballast as crushed stone and give it the same gradation requirements as recommended for crushed stone and crushed air-cooled blast furnace slag ballast, your committee recommends certain changes in the Manual.

Mr. President, I move the change in Specifications for Prepared Stone, Slag and Gravel Ballast as set forth on page 710 of Bulletin 549, be adopted and published in the Manual.

[The motion was duly seconded, was put to a vote, and carried.]

Assignment 11—Chemical Control of Vegetation, Collaborating with Signal Section and Communications Section AAR.

CHAIRMAN HARRIS: The next and final report will be on Assignment 11—Chemical Control of Vegetation. The subcommittee chairman, C. E. Webb, engineer of tests, Southern Railway System, will present the report. Mr. Webb.

C. E. WEBB: Mr. President, members, and guests:

The progress report appearing in the Bulletin covers the research on and evaluation of weed killer formulations at Iowa State College and North Carolina State College, together with field investigations by the AAR Research staff.

Numerous chemicals and chemical combinations have been tested during the past eight years, and much progress has been made; but as yet there is no chemical available that will solve all vegetation control problems found on railroads throughout the United States and Canada.

Relatively simple and inexpensive treatments can be effective if applied at the proper time and followed up consistently. Re-infestation that occurs through lack of continuous control may result in extreme difficulty in control in forthcoming years.

Observations this year substantiate the theory that a long-term system weed control program is superior to one on a year-to-year basis. Although the initial expense involved in such a program may be high, a reduction in cost may be realized over an extended period.

Vegetation control on track can be divided into root kill to eradicate perennials and top kill to eliminate annuals, or reduce interference of perennials.

Oils appear to have greatest merit for top kill. They are economical, non-hazardous for livestock, and not as susceptible to adverse weather conditions.

Root kill can be obtained by a herbicide translocated downward to the roots and by one that penetrates the soil and acts directly on the roots. These treatments are in general more expensive.

Low volatile ester formulations of 2,4–D and 2,4,5–T continue to be used extensively for controlling brush in all regions, with ammate being substituted for these compounds in areas adjacent to crops or in states where the use of phenoxy compounds are prohibited. Additional research is needed to determine optimum time and method of application.

At the present time, there are more than 50 materials available for the purpose of controlling weeds or brush on railroads. Each of these materials applied at the proper time at the recommended rate, has been used successfully, depending on type of vegetation, climatic conditions, length of growing season, type of soil, and type of control desired.

The report this year, and preceding years, particularly the tables showing specific results obtained in different regions with various compounds, and the table showing relative costs should be extremely valuable in providing unbiased and factual information on the results that may be expected.

There is every hope that continued evaluation of new products may result in better, and especially cheaper, weed killing products, and that oils may be improved possibly by the use of additives to make them more effective.

Chairman Harris: Mr. President, this concludes the presentation of our subcommittee reports.

Two years ago Committee 1 presented as its special feature an address by Rockwell Smith, research engineer, roadway, Association of American Railroads on "Soil Engineering Problems During the Construction of the Atlantic Railroad, Colombia, South America." Today we bring you a similar report, but from an entirely different part of the world where the conditions and problems were altogether different from those described by Mr. Smith. The gentleman who will speak to us this morning was born in England but later moved to Canada. He is a graduate of McGill University and has completed graduate work in Soils Engineering at Purdue University. After working on location surveys, he later served as district engineer during the construction of the Quebec North Shore & Labrador Railway and upon completion of construction of that railway, he was appointed soils engineer, which position he holds at the present time. He has an intimate knowledge of his subject, and I am sure you will be very interested in what he has to say. It is with a great deal of pleasure that I now introduce to you Robert W. Pryer who will speak to you on "Soil Engineering Problems on the Quebec North Shore and Labrador Railway." Mr. Pryer.

Soil Engineering Problems on the Quebec North Shore & Labrador Railway

By Robert W. Pryer
Soils Engineer, Quebec North Shore & Labrador Railway

Mr. President, Mr. Chairman, members, and guests:

In recent years the Labrador peninsula has become an important producer of iron ore. Although this, probably, is quite well known, it may not be generally appreciated that 10 years ago the interior of this large section of eastern Canada was relatively unknown.

It imbraces an area of nearly a half million square miles. It is entirely undeveloped, incompletely mapped, supports no permanent settlements other than a few isolated communities in coastal areas, particularly along the north shore of the Gulf of the St. Lawrence. It was also practically inaccessible except by air or on foot.

After several years of geological exploration in an area about 360 miles north of the Gulf of St. Lawrence and ground and aerial surveys of a proposed route between this area and Seven Islands, a small port on the north shore of the Gulf, construction of the Quebec North Shore & Labrador Railway began late in 1950. A total of 21 million cu yd of excavation was completed during the three years, and track laying was completed early in 1954.

In addition to construction of the roadbed a great deal of other work was also completed during this three-year period. The construction of several hundred miles of roadbed, two large tunnel sites, two substantial hydro-electric power developments, no fewer than 11 airstrips or handling facilities, docks, and terminals, and so on.

Seven Islands, the southern terminus of this railway, is still even at the present time somewhat of an isolated community which has no direct link with the national highway or railroad systems in Canada. It is thus accessible only by sea or by air. The closest railroad connection is some 140 miles away on the south shore of the Gulf. It is hardly surprising, therefore, that construction was complicated by problems of access and supply. It was also complicated by the severity of the climate.

Furthermore, since no engineering activity had previously been undertaken in this region, there was no background of information concerning the soils of this area. There was also lack of adequate climatological data. The object of this paper is to report upon the nature of the soils encountered during construction and also to note some of the problems involved.

In this connection particular importance is attached to the environment with which these soils occur. It is felt that much valuable information may be obtained from the study of such factors as physiographic history, climate, and vegetation. This is particularly true in cases such as the Quebec North Shore & Labrador Railway in which circumstances did not permit a comprehensive soil survey to be undertaken prior to construction. A physiographic approach is used because of the ease with which glacial land forms may be recognized on the ground, from the air, and more particularly in the aerial photographs. These land forms may, in turn, be correlated with definite soil types, and it is possible thus to make generalizations which are valid over a fairly broad area. Vegetation is important because it is found to be a sensitive indicator of moisture and drainage conditions.

In some cases the type of vegetation depends upon the type of terrain conditions. In other instances vegetation has itself helped to modify the terrain, as, for example, in the development of parks. Like land forms, vegetative patterns are also readily identified in aerial photographs.

Climate is considered to be important for several reasons. Severe temperature conditions cause the northern half of the Labrador peninsula to have inadequate drainage, with permanently frosted ground. Scattered islands of permanently frosted ground also occur south of the boundary of this area. The depth of seasonal frost penetration and the rate at which frost leaves the ground depends upon, among other things, precipitation, particularly precipitation in the form of snow. It has an important effect, therefore, upon drainage and moisture conditions.

Frost is also responsible for the weathering of rocks and sloughing of slopes in frost-susceptible soils and thus contributes to the landscape.

It is apparent, therefore, that with a limited amount of data one can make a thoroughly reliable estimate of soil conditions in this particular region through the careful interpretation of aerial photographs. This can be particularly helpful in planning more detailed investigations.

The first slide [See Fig. 1, page 670] shows the location of the railway.

It should be borne in mind that the Labrador peninsula forms part of the Canadian shield. It is thus a region of strong crystalline rocks. The bottom of that slide shows the Gulf of St. Lawrence, and to give you an idea of the scale, Schefferville, the northern terminus, is 360 miles away. The peninsula generally may be described as a plateau with an average elevation of between 1500 to 2000 ft. The southern edge of this plateau, the edge that fronts on the Gulf of St. Lawrence and the area shown in that slide below the word "Quebec" covers a distance of approximately 100 miles and has been severely dissected by south-flowing rivers and streams. These streams flow in broad glaciated valleys. Close to the coast an escarpment rises quite abruptly to an elevation of about 1000 ft. In many places local relief may be as much as 2000 ft in this area, and it is thus a particularly rugged region.

In the vicinity of Seven Islands, or Sept Iles as it appears on this slide, the southern terminus, the surface soils are beach deposits, loose, uniform, stratified sands. This emerging coastline and elevated beach ridges are conspicuous in the aerial photographs. These, therefore, give some clue to the nature of the soils. Leaving the narrow coastal plain, any transportation route to the interior must necessarily follow one of these river valleys. In the case of Quebec North Shore & Labrador Railway, it follows the valley of the Moisie River, then several of its major tributaries.

During the post-glacial marine invasion of this part of the world, massive deposits of silts and silty clays were deposited in the low reaches of the Moisie River valley and several of these other river valleys. These materials are particularly prone to landslides. It is a fairly common occurrence throughout Eastern Canada. They are highly sensitive to any kind of disturbance. Here again aerial photographs are a source of useful information.

The larger landslides, the ones which develop into flowslides, tend to leave massive scars in the river banks.

Still within the river valleys, but north of the area affected by these sensitive silty clays, stratified sands and gravels, are the predominant surface materials. Generally these soils are coarse textured and well drained and are excellent embankment soils. Occasionally silt and frost-susceptible fine sands occur, but their presence can often be correlated with, or inferred from the longitudinal profile of the adjacent river. Fine-textured soils usually are found in sections where the river is sluggish or a meandering stream rather than a swiftly flowing river. The principal soil formation is on the interior plateau, the area north of the word "Quebec," the lake plateau is a sandy glacial well-graded soil and an excellent embankment material when not excessively wet. Unfortunately, much of the terrain is waterlogged, and it is often difficult to excavate and place these soils unless adequate provision is made for drainage.

This situation is aggravated to some extent by climatic conditions. Although rainfall is not unduly heavy, it is an almost daily occurrence during the summer season.

Granular land forms, particularly eskers, are a valuable source of material for use as borrowed or prepared gravel ballast and sub-ballast and have often served as the foundations for airstrips, since they require a minimum amount of grade.

In the vicinity of the lakes which comprise a great part of the area of the interior plateau, lacustrine silts and sands are not uncommon. These soils usually occur in

shallow strata which overlie the sandy glacial till. They are highly frost-susceptible and can be particularly troublesome unless care is taken to exclude them from subgrades and embankment.

The term "muskeg," is used to describe a variety of poorly drained wet surfaces on the Labrador plateau. Two principal types of this organic cover are recognized—the open and timbered bogs. Timbered bogs usually occupy shallow depressions within the drainage basins of the larger lakes. Open or string bogs tend to develop on gentle slopes with poor internal drainage, and even in areas where sandy soils predominate, the long freezing season and late date at which the ground becomes free of frost cause the drainage of spring melt-water to be impeded, and provide ideal conditions for the spread of mossy vegetation.

The water-retaining properties of this type of vegetation still further impede drainage, and thus aid in the development of bogs, particularly string bogs.

The next slide [See Fig. 6, page 679] is an example of the type of problem which is likely to occur in the banded sediments of the lower Moisie River Valley. This is a simple rotational slip which was probably caused by a local instability of the toe of the cut slope. Stability analyses are complicated by the lack of uniformity in these soils. Presence of buried permeable strata and the inclination of the bedding planes are two important considerations.

The next slide [See Fig. 7, page 681] also shows the banded sediments of the lower river valley, and this is an example of the condition which can arise from the thawing of ice. The interiors are particularly susceptible to the formation of ice lenses. Although frost penetration is not very great, the soils are too wet. Ice lenses do form and provide ideal sliding surfaces as far as slopes warm up in the spring. This type of condition is easily remedied, of course. All these slopes have now been moved back a respectable distance from the end of the ties and drainage provisions made both at the shoulder slopes, the toe slopes, and in some cases lateral drainage has been resorted to with some success. As these slopes weather, they tend to become more tolerant of vegetation, and it is hoped eventually they will be covered with a vegetative blanket. In other cases they have been buried with some success in granular embankments.

The next slide [See Fig. 8, page 682] is an example of the stratified sands and gravels which occur in the more northerly sections of the river valleys. These slopes have heights from the shoulder down to the river of about 250 ft. The materials are in no way troublesome in themselves, but unfortunately many of these slopes are underlain by rock terraces. Perched lakes and water tables also occur on the upper surfaces of these terraces, and seepage can be a problem, particularly when these slopes are underlayed at no great depth by smooth, glaciated rock surfaces. In many cases it has been necessary to drain lakes and shoulders of these areas and also to excavate the slopes. They have been the source of some difficulty.

The next slide [See Fig. 4, page 676] shows grain-size distribution curves for typical glacial till materials. It can be seen in general these soils are well graded and do not contain much more than 20 percent silt. Less than 20 percent silt sizes has been found to be not seriously frost susceptible. Soils such as that represented by the upper curve in which there is perhaps 40 or 50 percent silt size particles are seriously frost susceptible, and are very troublesome soils in the few instances where they have been incorporated in the embankments.

The next slide [See Fig. 5, page 677] is an example of conditions which can arise in cuts in these materials. Although they are not particularly troublesome with normal water contents, that is an example of the type of thing that can happen unless drain-

age measures are resorted to early in construction. The object in the foreground is a tractor buried almost to the wings.

This slide [See Fig. 10, page 684] represents two very similar soils—one placed with the water content slightly below optimum, the other with water content somewhat greater, about 4 percent, sufficient to make the soil represented by the upper curve extremely unstable. That is the material you saw in the previous slide. Material represented by the lower curve was perfectly stable and able to carry traffic during the construction.

The next slide is an example of muskeg conditions. That is an example of vegetative pattern. Note the string bogs. In general these organic materials are not unduly deep, 3 or 4 ft of organic material, and are not too difficult to excavate. In general, however, as long as there was at least 6 ft of fill, no attempt was made to excavate them. We simply filled across these muskegs. They have settled, consolidated rapidly, and have given little trouble. However, they are frequently underlain by the lacustrine silts and sands which are perhaps not very deep, but when the fills are shallow enough, frost penetration can reach these highly frost-susceptible soils. Then serious frost heaving can occur. That again is relatively easy to remedy by raising grade and wide embankments.

The next slide [See Fig. 9, page 683] is an example of a completed section of subgrade. That is to say it had been finished and left very shallow-cut. You see what happened in wet weather. It was necessary to raise the grade and fill in this particular situation.

The next slide, please. This is an example of ice lensing in these frost-susceptible lacustrine silts and fine sands. The dark lines throughout the photograph are minute ice lences which are there so fine that they can readily escape notice unless care is taken to pick them out.

The next slide is simply one which shows the north trail and the only substantial bridge crossing on this particular line.

To summarize then, soil problems in construction and maintenance in this area are related to two things, the excavating and placing of wet soils and frost-susceptible soils also the stability of soils in the banded sediments. Thank you. [Applause]

Chairman Harris: Mr. Pryer, on behalf of the Association, and especially Committee 1, I wish to thank you for a very interesting and most constructive talk.

I think I might mention at this time that Mr. Pryer and Rock Smith and I up until about an hour ago were in a cold sweat. Mr. Pryer's slides were lost, and at the last minute we had to have these slides made. We got them just before the committee came to present its report.

This concludes the report of Committee 1.

President Meyers: Thank you, Mr. Harris. Your committee with the assistance of Mr. Magee and his staff, a number of railroads, and several colleges and universities has presented another group of very interesting and informative reports. We thank you for this. I also want to thank Mr. Pryer for his very interesting presentation here this morning.

Mr. Harris, we appreciate the energetic leadership which you have given to Committee 1 during your first year as chairman. Your committee is now excused with the thanks of the Association.

Closing Business Session—March 11, 1959

[President Meyers presiding.]

PRESIDENT MEYERS: I think you might be interested in the total registration—1433 railroad members and guests and 828 other guests, a total of 2261.

We are a little bit behind schedule, but I think you will agree the reports and talks this morning have been most interesting. With the presentation of the report of Committee 1, we have completed consideration of the committee reports to come before this Annual Meeting. Accordingly, we will now begin our Closing Business Session which will include the installation of our new officers for the ensuing year.

However, before doing this I want to express my appreciation to everyone who has participated in the program and to all of those who have contributed toward the work of the Association during the past year. Measured by the wealth of information which has been presented to us here at this convention, I think our 1959 Convention has been quite successful.

Realizing the impossibility of absorbing all that has been said here during the past two and a half days, I am sure many of you will want to review the transcript of the convention when it appears in the 1959 Proceedings, and I would particularly recommend this to those of our members who for one reason or another could not attend our convention. Also before beginning the closing business, I would like to make a couple of announcements. One is so that you will remember the inspection trip this afternoon to the AAR Research Center on the campus of Illinois Tech, beginning at 1:30 pm. Mr. Magee and members of his staff will be pleased to show you their facilities and answer questions about the work.

Secondly, I would like to remind all members of the Board of Direction, including the newly elected and the retiring members, that they are invited to a luncheon after the close of this meeting in the Louis XVI room with members of the Convention Arrangements Committee. Following this luncheon there will be the usual post-convention meeting of the Board of Direction.

I now call to order the closing business session of this convention. Is there any business to come before us?

PAST PRESIDENT H. S. LOEFFLER [Great Northern]: Mr. President, may I have the privilege of the floor?

Mr. President, during the past year you have handled the affairs of the American Railway Engineering Association in an effective and able manner. The object of our Association as stated in our Constitution is, briefly stated, as follows: "To advance the knowledge pertaining to the scientific and economic location, construction, operation, and maintenance of railways."

It is recognized that through your efforts substantial progress has been made in advancing the object of the Association. On behalf of the American Railway Engineering Association it is my privilege at this time to present to you a plaque as an expression of appreciation for your leadership and service to the Association.

This plaque reads as follows: "The American Railway Engineering Association records its grateful appreciation to B. Robert Meyers for his able administration of the affairs of the Association during his term as President, 1958–1959."

Congratulations, Bernie, for your great success.

PRESIDENT MEYERS: Thank you, Stan. [Applause]

This is certainly a beautiful plaque and I know just the spot for it. The presentation of this plaque is certainly the final highlight of my term as President. Many things

have happened here I am sure that I will always remember—more than just the "bricklayer" subjects or the official subjects.

Thank you, Mr. Loeffler. It is a pleasure to get this plaque from the senior Past President of the Association attending this convention, and one who has been a personal friend of mine for at least 20 years. This brings me back right where I started. Thank you very much.

Each year the close of our Annual Meeting brings to an end the services of several members of our Board of Direction. This year the Annual Meeting marks the end of the service on the Board of Past President Wm. J. Hedley, chief engineer, Wabash Railroad, under the clause of our Constitution which specifies that past presidents remain on the Board for only two years following the completion of their term of office as president.

The Association is greatly indebted to Mr. Hedley for his long and valued service to the Association in an official capacity, and for his special service on a number of Board Committees. In his retirement from the Board, we shall miss his always sound counsel and advice. If Mr. Hedley is present, I would like him to stand and be recognized. [Applause]

With the close of this Annual Meeting, the terms of office of four other members of the Board of Direction terminate. These are G. H. Echols, chief engineer, Southern Railway System. Mr. Echols. [Applause]

L. A. Loggins, chief engineer, Southern Pacific Lines in Texas and Louisiana. [Applause]

R. R. Manion, assistant vice president—operation, New York Central System. I don't think Mr. Manion could be here.

And, W. G. Powrie, chief engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad. Is Mr. Powrie here? Apparently not.

All of these men have served your Association well, and any words, I might say would be inadequate to express our appreciation to them.

Having observed since early last fall the tremendous amount of work which has gone into the planning and arrangements for this convention, and during the past two and one-half days in the execution of these plans, it is impossible for me to express adequately my appreciation to all of those who have contributed in the development of these plans and their execution, but I do want to express my most sincere appreciation to Chairman Barnes and the members of his Committee on Convention Arrangements, to our secretary's office, and to all those ladies who assisted Mrs. Meyers in planning and carrying out the social features of our convention for the ladies.

Having been chairman of the Convention Arrangements Committee in 1951, and now having observed at close range the work of our present Arrangements Committee, no one knows better than I the multitude of details to which they have given their attention in order that our convention might be a success, with maximum convenience and pleasure for all those in attendance. So to all the members of this committee, and to all those who assisted in making the women's functions most enjoyable, Mrs. Meyers and I want to say, "We thank you."

It is now my great pleasure and privilege as your retiring president to introduce to you the Association's new officers for the ensuing year. Our senior vice president for the year ahead is E. J. Brown, chief engineer, Burlington Lines, who under the Constitution automatically advances to this position from that of junior vice president. Mr. Brown, will you please come to the platform.

As your new junior vice president, you have elected R. H. Beeder, chief engineer of the Santa Fe System. Mr. Beeder, as you will recall, was a director of our Association for three years prior to the end of our 1958 convention. I will appreciate it if Mr. Beeder will come to the platform and take a place alongside Mr. Brown.

Mr. Brown and Mr. Beeder, I congratulate both of you upon your elevation to high office in our Association. This places on you further obligations, but, at the same time, it gives you new opportunities to serve our Association. I know that you will live up to these further obligations and opportunities for service.

As your president for the year ahead, you have elected F. R. Woolford, chief engineer, Western Pacific Railroad. I have asked Past Presidents Blair and O'Rourke to escort Mr. Woolford to the platform, and I would appreciate their doing so at this time.

[Past Presidents Blair and O'Rourke escorted Mr. Woolford to the platform and the assembly applauded.]

PRESIDENT MEYERS: It is a great honor and privilege for me to proclaim you the newly-elected president of the American Railway Engineering Association. You are highly deserving of this honor, and are well qualified for this high office. Accordingly, it is with pleasure and confidence that I turn over my responsibilities as president to you.

In doing so, I want to present you with this solid gold emblem of the Association, which bears the engraved words on the back—"F. R. Woolford, President, 1959–1960." I know you will wear it with distinction to yourself and the Association.

[President Meyers presented the gold emblem of the Association to the newly-elected president, F. R. Woolford. Mr. Woolford assumed the chair as the newly-elected president.]

PRESIDENT-ELECT WOOLFORD: Thank you, Mr. Meyers, and fellow members of this great Association. Words cannot express my appreciation for your having bestowed upon me today this great honor of being president of America's foremost engineering association. Little did I think when I joined that field party on the Missouri Pacific in the early 1920's, that this day I would be so honored by you men. Thanks for the confidence you have placed in me.

Bernie, your administration has been a most successful and inspiring one. May I have the great fortune to hold the same interest of our membership that you had for the continuation of the worth-while accomplishments of our Association.

Friends, no one individual can ever hope to successfully pilot such an outstanding group as ours. I ask your continuing help, and with it I am certain nothing can hinder our attainments. The better half of my team, that willing helper who is always watching over me, is at this moment looking down from the balcony—my regards, Kathleen.

As a goal for our oncoming year, may I place before our membership, "Further Attainments of Standardization of Track Materials." With your help we can make standardization a reality, first through area acceptance, that is, acceptance by Northern, Southern, Eastern, and Western rail groups, followed by a unification of these four areas into one, or in other words, full standardization.

All of you gentlemen heard the wonderful report that our Committee on Track gave this morning, especially the special address by Mr. Zeeman. To accomplish what he proposed, I think we will have to forget about personalities and individuals and work toward standardization as a group. This we can do, and I am asking you to at least put it on the road in that direction this year.

Will all of you please direct your efforts in that direction for the betterment of our American railroads. Thank you. [Applause]

A. W. CARLSON [Western Pacific Railroad]: President Woolford, on behalf of the Engineering Department of Western Pacific, I would like to present you with this gavel.

It is a very fine one, and all the members of the engineering and maintenance of way personnel under your direction have contributed to it.

As you are the first Western Pacific—in fact, the first Far-West AREA president—we are very proud, and with this gavel we give our best wishes.

PRESIDENT-ELECT WOOLFORD: Thank you, Mr. Carlson. [Applause]

Thank you for such a thoughtful remembrance, exemplified by this beautiful and useful instrument. I doubly appreciate it as coming from the boys under, as you say, my direction, although they direct themselves out on the West Coast, on the Western Pacific. With such an energetic and capable Board of Direction the membership has provided me, I doubt if I will find any real need for a gavel.

W. M. JAEKLE [Southern Pacific Company]: President Woolford, I also have a gavel for you. It comes with the best wishes of Vice President Harry Munson. He asked me to present it to you on behalf of your good friends and associates in all parts of the West and Pacific Coast. My best wishes from there.

PRESIDENT-ELECT WOOLFORD: Thank you. [Applause]

Gentlemen, I don't know what I will do with two gavels, maybe I will use one in each hand, but as I said before, with the energetic and capable Board of Direction the membership has provided me, I doubt if I will find any need for even one gavel, let alone two. Nevertheless, thanks for the thoughts.

It is now my pleasure to present to you the four men you have elected as new members of the Board of Direction. As I call their names, I would appreciate their coming forward and standing in front of the speaker's table.

W. E. Cornell, engineer of track, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

F. L. Etchison, chief engineer, Western Maryland Railway, Baltimore, Md.

W. J. Cruse, engineer maintenance of way, Great Northern Railway, St. Paul, Minn.

C. R. Riley, chief engineer, Baltimore & Ohio Railroad, Baltimore, Md.

As you may or may not know, in view of his official retirement from railroad service as chief engineer of the Norfolk & Western Railroad, effective July 1, A. B. Stone has resigned as a director of our Association, effective with the close of this convention. In view of this, at a special meeting of the Board last evening, C. J. Henry, chief engineer system, Pennsylvania Railroad, Philadelphia, Pa., was elected to fill Mr. Stone's unexpired term of office extending to March 1960.

I would be pleased if Mr. Henry would come forward and stand with our other four new directors.

Gentlemen, I congratulate you upon your election as directors of this Association and welcome you to the Board of Direction. It is an office of high honor and responsibility which you assume, but I know you will meet its responsibilities; that you will enjoy your association on the Board for the next three years; and that you will bring much of value to its deliberations.

Before we adjourn, I should like to announce again a meeting of the Board of Direction this afternoon at 2 pm in the Orchid Room, following a joint luncheon of the Board and the Committee on Convention Arrangements in the Louis XVI Room immediately after the close of this meeting.

Is there any further business to come before us? If not, I now declare the 58th Annual Meeting of the American Railway Engineering Association adjourned.

[The meeting adjourned at 12:25 pm.]

MEMOIR

MEMOIR

Armstrong Chinn

Died August 28, 1958

Armstrong Chinn, president of the Terminal Railroad Association of St. Louis, and past president of the American Railway Engineering Association, passed away in his sixty-fourth year at Barnes Hospital, St. Louis, Mo., following surgery. With profound regret the Association expresses its sorrow for the loss of an honored, capable and devoted member.

In addition to Mrs. Chinn, he is survived by a daughter, Mrs. D. S. Sears, Richmond, Va.; a son, Armstrong Chinn, Jr., Miami, Fla.; a sister, Miss Elnear Chinn, and a brother, B. S. Chinn, both residing at Miami, Fla.; and another brother, Carter Chinn, St. Paul, Minn. To this family the membership of the American Railway Engineering Association expresses sincere and deeply-felt sympathy.

Mr. Chinn was born at Dallas, Tex., on September 26, 1894, the son of William

Armstrong Chinn

Yates and Katherine (Armstrong) Chinn, but considered himself a Virginian. He spent his youth in Virginia, the state where his ancestors settled in 1650 and where he secured his education.

He attended the public schools of Norfolk, Va., and after graduating from high school secured his technical education at Virginia Polytechnic Institute, Blacksburg, Va., where he earned a B.S. degree in C.E. in 1915, and a C.E. degree in 1916.

Mr. Chinn began his railroad career during the summer vacations of 1912 and 1913 as a rodman on the old Wheeling & Lake Erie Railroad. In the summer of 1914 he worked as an instrumentman for the county surveyor of Norfolk County, Va. Subsequent to his graduation from V.P.I., in June 1916, he was employed by the Chicago, Burlington & Quincy Railroad as an instrumentman, first at Aurora, Ill., and later at St. Louis, where he was working when he entered military service. From January 1918 to June 1919, he served with the Armed Forces in France as a second lieutenant, field artillery.

Following the close of hostilities Mr. Chinn returned to the Chicago, Burlington & Quincy as instrumentman in July 1919, and on April 6, 1920, he and Edith Elizabeth Shumadine were married.

In the same year Mr. Chinn joined the American Railway Engineering Association. He was sincerely interested in the projects of the Association and was active in committee work, giving generously of his time to Committees 4, 5, 11, 13, 22 and 24 over the years. He served with distinction on these committees and his recognized ability and judgment were rewarded with his election to the Board of Direction, 1940–1943, and as president of the Association, 1947–1948. He became a Life Member in 1955. As president he also was chairman of the Construction and Maintenance Section, Engineering Division, Association of American Railroads, and of the Engineering Division as a whole. In his Association activities he set an enviable record of years of loyal and efficient service, applying rare tact and an extraordinary administrative capacity. The American Railway Engineering Association has lost a valuable member with recognized qualities of inspiring leadership.

In addition to being a member of the AREA, Mr. Chinn was affiliated with the following technical and professional organizations: member, American Society of Civil Engineers; past president, Roadmasters' and Maintenance of Way Association; past president, American Railway Bridge and Building Association; past president, Maintenance of Way Club of Chicago; member, Mississippi Valley Maintenance of Way Club; member, Western Railway Club; member, Engineers Club of St. Louis; and member, Locomotive Maintenance Association—truly a record of achievement extending over many years. His personal dedication and unstinting energy, far beyond the call of duty, given towards the advancement of railroad engineering, is a model for all to emulate. He was a man of vigor and drive and evinced those qualities of character in his progress to the top of his chosen professional organizations as he did in the railroad industry.

He rose progressively through various positions in the engineering and maintenance of way departments of the Chicago, Burlington & Quincy to that of district engineer maintenance of way in 1927. Two years later he became chief engineer of the Alton Railroad (now part of the Gulf, Mobile & Ohio), advancing to general manager in 1943, and to chief executive officer in 1945, the position he held at the time of his election in 1946 to the presidency of the Terminal Railroad Association of St. Louis. During that period he served with selfless zeal and devotion to the advancement of the industry. The following quotation is from the memoir of the board of directors of the Terminal Railroad Association of St. Louis:

"Mr. Chinn achieved outstanding success as a railroad executive and as a civic leader, and the period of his presidency of the Terminal Railroad Association of St. Louis was marked by significant progress in the affairs of the company. Forthright and vigorous, sound in judgment, he possessed to an unusual degree the capacity of making friends and winning the loyalty and respect of all who served under him. His keen intellect, integrity, and splendid character and personality commanded the confidence and affection of all who knew him, and his death is a personal sorrow to his many friends and associates, as well as a distinct loss to the railroad industry."

In addition to his professional activities, Armstrong Chinn lived an active and rewarding life in his community. Despite the demands of his occupation he devoted much time to his civic duties. He took a profound interest in the affairs of the City of St. Louis and the community served by his railroad, and his participation in numerous civic activities gave his city the benefit of wise counsel and vigorous leadership. He was a member of several committees which assisted the mayor in recommending solutions of financial and civic problems. When he was a member of the board of direc-

tors and executive committee of the St. Louis Chamber of Commerce, he took an active interest in that organization. An outstanding achievement in which he participated was a satisfactory solution of the long-standing riverfront problem which had plagued the Terminal Railroad Association of St. Louis and the riverfront commission for many years.

Armstrong Chinn found time to become an active and valued participant in the affairs of many organizations. He was a member, American Legion; member, Friends of Land; chairman, Rail Transportation Civil Defense, Greater St. Louis-E. St. Louis Area; operating officer, Region II, Illinois Railroad Civil Defense; chairman, Board of Managers, St. Louis Railroad YMCA; member of board, St. Louis Council, Boy Scouts of America; member of board, St. Louis Governmental Research Institute; member of board, St. Louis Crime Commission; member, Traffic Club of St. Louis; director, USO; member of board, Missouri Public Expenditure Survey; member of board, St. John's Methodist Church; member, American Society of Traffic and Transportation; member, National Defense Transportation Association; member, Masonic Order, Scottish Rite Bodies and Moolah Temple; member, Bellerive Country Club; member, Missouri Athletic Club; member, Noonday Club; and member, Union League Club, Chicago.

Armstrong Chinn was a religious man and was active as a member of the board of stewards of St. John's Methodist Church, and as a member of the board of the St. Louis Council of the Boy Scouts of America. As chairman of the board of the local Railroad YMCA, he was instrumental in bringing about many improvements in facilities and service. In all of these organizations he will be remembered with gratitude and esteem.

By those who had a casual business acquaintance with Mr. Chinn, he will be remembered for his gentlemanly courteousness. By those who had the privilege of knowing his intimately, he will always be revered for his sterling character, friendliness and interest in the ambitions and hopes of others, his desire to give wise counsel when requested, and his generous nature and loyalty to his friends and associates. His smile, his handshake, his friendly words of greeting will long be remembered.

The American Railway Engineering Association, the entire railroad industry, and society in general have suffered a grievous loss in his passing.

G. M. O'Rourke, *Chairman,*
T. A. Blair
E. J. Brown
Wm. J. Hedley
W. H. Hobbs
Committee on Memoir.

REPORT OF THE EXECUTIVE SECRETARY

March 1, 1959

TO THE MEMBERS:

One year ago at this time, with the railroads, along with the country as a whole, in the throes of an economic recession, the welfare of your Association for the year ahead, compared with the year just closed and immediately preceding years, was a matter of concern to your officers and your secretary. Could the Association count on the continuing high level of interest and effort of its members and the support of the American railroads? Would it be able to continue unabated its productive work? And could it maintain its favorable financial condition?

Now, 365 days later, the record happily shows all of these questions answered in the affirmative. The Association did retain the interest and effort of its members, and the backing of the railroads. It did continue its work unabated; and it did close the year in a favorable financial condition. In fact, in all of these respects, the adverse economic conditions to the contrary, the Association moved into higher ground—a significant achievement. Only in the matter of total membership did the Association take a backward step—due largely to the inability of the railroads to augment their technical staffs with the usual number of new men, on the one hand, and an increased number of resignations from membership resulting from the retirement of older members, on the other hand—total membership falling from 3362 as of February 1, 1958, to 3310 on February 1, 1959, a reduction of 52. But, unfortunate as this loss was, the fact that it was not larger under the conditions which prevailed, was also a favorable aspect of the Association year.

That this generally favorable report can be made was not the result of a "business as usual" attitude on the part of either the officers and directors of the Association or its members generally—although, assuredly, the inherent vitality of the Association purposewise, interestwise, and financially, would have seen it through on a high plane.

Committees Asked to Tighten Up Operations—Step Up Effort

Aware of the conditions confronting the Association, your officers and directors early set in motion measures to bring about a belt-tightening all along the line. These affected to some extent a number of aspects of Association activity, but were directed primarily to minimizing the travel and off-the-job time of the more than 1100 members of the Association involved in committee work, and the attendant expenses of these members and their railroads, while precluding at the same time any let-down in the effectiveness and productivity of committees.

To this end, the Board, immediately at the beginning of the Association year—both directly and through the Association's monthly News—asked all AREA committees to adhere closely to the Association's rule calling for the holding of committee and subcommittee meetings at points most convenient to the majority of members and the holding of subcommittee meetings in conjunction with committee meetings to the fullest possible extent. It also asked committees to shorten their meetings to one day wherever possible—avoiding three-day meetings completely; and to eliminate all inspection trips in connection with their work, unless they did not have the effect of extending meetings an extra day. Further, it asked committee chairmen, working through the secretary's office, to preclude to the fullest extent possible, meetings concurrent with those of other committees, in order to minimize the number of members on any

Committees of The Board of Direction

1958–1959

Executive Committee

B. R. Meyers (chairman), Ray McBrian, F. R. Woolford, E. J. Brown, G. H. Echols

Assignments

G. H. Echols (chairman), Wm. J. Hedley, A. V. Johnston, J. C. Jacobs, T. Fred Burris

Personnel

W. H. Hobbs (chairman), A. B. Stone, F. R. Woolford, L. A. Loggins, W. M. Jaekle

Publications

A. B. Stone (chairman), E. J. Brown, R. R. Manion, W. H. Hobbs, T. M. von Sprecken

Manual

L. A. Loggins (chairman), W. W. Hay, Ray McBrian, T. M. von Sprecken

Membership

R. R. Manion (chairman), G. H. Echols, W. G. Powrie, A. V. Johnston, W. M. Jaekle

Finance

J. C. Jacobs (chairman), E. J. Brown, W. G. Powrie

Special AREA Services

F. R. Woolford (chairman), Wm. J. Hedley, W. W. Hay, T. Fred Burris

Research

E. J. Brown (chairman), C. J. Code, Ray McBrian

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railroad being away from their headquarters at the same time—especially if in the same department.

Supplementing this action on the part of the Board, the president of the Association, in a Message to Members in the May issue of the News, called upon committees to keep up the standard of their work while holding to the minimum expenses in connection with their meetings. In this latter regard, he suggested they do more of their work by correspondence. At the same time, he urged them to maintain an open and inquisitive mind and to dig into all aspects of their assignment. Later in the year, "to help keep the ball rolling," the secretary of the Association, in a message to committee members in the November issue of the News, urged them to close the year with a strong finish and to emulate as a whole the high quality of the first committee reports

being received for publication, which, for the most part, he said, were more comprehensive in extent and treatment than similar reports of some previous years.

That these requests and admonitions did not fall on deaf ears was testified to in every aspect of committee activity throughout the year, referred to later in this report under Activities of Committees.

In a further effort to minimize the away-from-the-job time of committee members and to reduce their expenses, the Board also cancelled a contemplated meeting of all committee chairmen in April, intended as an indoctrination course for new committee chairmen and a refresher course for the other chairmen on the manifold rules and practices of the Association pertaining to their responsibilities and committee work. This meeting was cancelled reluctantly, because it is generally agreed that the increased effectiveness of committee work possible through the greater knowledge and efficiency of committee chairmen themselves, gained through attendance at such meetings, more than compensates for the time and expense involved on the part of committee chairmen.

At the same time, to increase its own efficiency, the Board of Direction sponsored successfully through amendments to the Constitution of the Association the creation of a five-man Executive Committee of the Board to function in its behalf during intervals between meetings of the Board on matters which cannot or should not be delayed; the simplification of the names of its various committees and, in some cases, clarification of their duties; and the giving of permanent status to the Board Committee on Research, which had been set up as a special committee in January 1958.

On the more positive side, the Board of Direction made a number of other important decisions and contributions during the year. Among these, it continued to encourage and support the research activities of committees; continued its practice of being represented, through one of its members, insofar as possible, at least one meeting of each committee during the year—to maintain closer liaison with the committees; authorized further revisions in and additions to the Information and Rules for the Guidance of Committees to set forth new or improved practices, or to clarify existing rules and procedures; saw through to completion, in July, the publication of the new General Subjects Index for the Manual, authorized in 1957; and took the first steps toward increased attention on the part of the Association to the matter of standardization.

In one of the more pleasing actions of the Board during the year, it authorized, on behalf of the Association, jointly with the American Iron & Steel Institute, the presentation of a bronze plaque to the University of Illinois, honoring Dr. Herbert F. Moore, Emeritus Research Professor of Engineering Materials, University of Illinois, in recognition of his pioneering and pre-eminence in the study of the fatigue properties of metal, and especially his successful direction, from 1931 to 1944, of the joint AREA–AISI Investigation of Fissures in Railroad Rail. To give added significance to this action, the Board then participated in the plaque presentation ceremony at the University, on November 7, which it did in conjunction with its regular November meeting, which was scheduled on the University campus to conserve the time and expense of Board members.

In August 1958, the Board also authorized the reprinting in 1959 of 20,000 to 28,000 copies of the Association's recruiting brochure "The Railroad Field—A Challenge and Opportunity for Young Engineers" (then being revised by the Committee on Cooperative Relations with Universities), for distribution to the engineering colleges of the United States and Canada over a three-year period. More detailed reference to this brochure is included later in this report, under Publications.

1958 Convention and Accompanying Exhibit

The springboard for the successful activities of the Association during the past year was, unquestionably, the highly successful and unusually well attended annual convention of the Association, March 11–13, at the Sherman Hotel, Chicago, with the accompanying large exhibit of equipment and materials at the Coliseum, sponsored by the National Railway Appliances Association.

The 1958 convention had a registration of 1433 railroad men and 828 other-than-railroad men—a total of 2261, not including the registration of 353 women. This was the second highest convention registration in the history of the Association, being exceeded only by that of the exhibit year 1955, when the total registration was 2378.

The program for the 1958 convention included reports on 122 of the 178 assignments of committees, and 17 special features in the form of addresses, illustrated papers, panel discussions, and motion picture presentations, and was noteworthy in several other respects. One of these was the convention keynote address of William T. Faricy, who, at the time, was completing his service as chairman of the board and chief executive officer of the Association of American Railroads. Another was a special luncheon tendered Mr. Faricy in his honor at the close of the Opening Session. Still others were the recognition given to the top officers of all AAR divisions, sections and bureaus in Chicago, at the speaker's table during Mr. Faricy's address, and the presentation at the Opening Session of framed Certificates of Honorary Membership in the Association to Mr. Faricy, and to Past Presidents C. H. Mottier, T. A. Blair, C. J. Geyer, and, posthumously, to Past President C. G. Grove. Included among the highlights of the convention also, of course was the Association Annual Luncheon, addressed by G. B. Aydelott, president of the Denver & Rio Grande Western, which was participated in by 1124 members and guests who filled to near capacity the Grand Ballroom of the hotel.

Speaking of the hotel, it should be stated that, both as to adequacy of convention facilities and room accommodations, and in the service of its personnel to the Association and convention guests generally, it met all expectations—a fact which led to the decision of the Board of Direction to return to the Sherman Hotel in 1959.

MEMBERSHIP

Continued growth in membership was the one major factor in Association activity that did not obtain in 1958. In spite of the fact that 155 new members were taken in during the year, February 1, 1958, to February 1, 1959, membership fell off from a total of 3361 at the earlier date to 3310 at the latter—a reduction of 52. This drop resulted in a break in the unbroken record of increase in membership of the Association yearly since 1944, even though that increase in recent years has been relatively small in any one year.

Disappointing as is this drop in membership, the fact that it was not greater under the depressed business conditions which prevailed throughout most of the year—especially on the railroads—is cause for satisfaction, indicating that the Association is not considered a fair-weather organization by its members.

Once more the membership record with regard to Junior Members was unfavorable, as the year ended February 1, 1959, saw the number of Junior Members in the Association decline still further to 86, from a total of 101 as of the same date in 1958—continuing a decline which took place in each preceding year back to that ended February 1, 1953, when Junior Membership was at the peak figure of 261. This further decline in the number of Juniors came about through the transfer of 21 to the

grade of Member and the dropping of 21 for non-payment of dues or failure to transfer to the grade of Member upon reaching the age of 30, while only 27 new Junior Members were taken into the Association.

If there has been any valid explanation for this continued decline in the number of Junior Members in past years, it was certainly valid during the past recession year. In view of this, it is not without significance that during the year ended February 1, 1959, compared with the preceding year, 18 fewer Juniors were dropped for failure to pay dues or to transfer to the grade of Member upon reaching the age of 30, and 4 more Juniors were taken into the Association—27 compared with 23.

With an eye constantly on the developing membership record throughout the year, neither your secretary nor the Board of Direction was unaware of the membership deficit in prospect for the year as a whole, and both were much concerned. However, in the light of economic conditions, it appeared impracticable to attempt to bolster the membership by any means other than personally encouraging membership among those clearly eligible and in a position to consider such, while at the same time adopting measures which would retain present members by making the Association of even greater value to them.

Unquestionably, the latter procedure must always be high in the order of business of the officers and directors of the Association, and, no doubt, under the adverse conditions which prevailed during 1958, giving emphasis to measures to retain the interest of present members was the most effective and practical course. However, in the light of the generally improved economic conditions presently prevailing on the railroads and in prospect for the year ahead, and especially as the railroads increasingly stabilize their engineering and maintenance forces, and augment them with new technical graduates to carry out enlarged construction and maintenance programs, those directing the policies of the Association will undoubtedly want to encourage all those measures which will further expand Association membership in order to make the benefits of membership of value to the greatest number. Among these measures is certain to be an effort on the part of the officers and directors themselves to encourage membership in the Association among eligible non-members in their respective organizations, and a request from them that members generally do likewise—keeping in mind that many of those who aspire to membership, or would be receptive thereto, often hesitate to take the necessary steps to gain such without an invitation or suggestion to do so from their associates—especially of a higher rank. This effort, to be effective, must be a concerted one, and should cover every eligible candidate for membership on the railroads, including the newest technical employees, those older technical employees in both office and field forces who may have thought they could get along just as well without membership. Made fully aware of the storehouse of practical information available to them through the publications of the Association and at least some part in its activities, it should not be too difficult to convince many in this latter group that they have been mistaken.

During the year ended February 1, 1959, the Association suffered the loss through death of 46 members, as set forth in the roster of deceased members at the end of this report. Among these were 2 past presidents, one of whom was also a past committee chairman; 1 committee chairman; 2 other past committee chairmen; and many others who had actively participated in committee work.

The two past presidents were W. P. Wiltsee (1933–1934), retired chief engineer of the Norfolk & Western, and chairman of Committee 5—Track, 1919–1925, who died on February 3, 1958, and Armstrong Chinn (1947–1948), president of the Terminal

Membership

(February 1, 1958, to February 1, 1959)

Members on the rolls February 1, 1958	3362
New members	155
Reinstatements	27
	3544
Deceased	46
Resigned	68
Dropped	105
Net Loss Juniors (transferred 21; dropped 21; additions 27)	15
	234
Net loss	52
Membership February 1, 1959	3310

Membership Classification as of February 1

	1953	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*
Life	375	401	436	465	470	469	482
Member	2312	2366	2381	2414	2478	2524	2491
Associate	289	270	274	261	258	268	251
Junior	261	220	187	163	144	101	86
Totals	3237	3257	3278	3303	3350	3362	3310

Railroad Association of St. Louis, who died on August 28, 1958. A memoir on Mr. Wiltsee appears in Vol. 59 of the Proceedings for 1958, and one on Mr. Chinn appeared in Bulletin 546, for November 1958, and will be carried over into the 1959 Proceedings.

The committee chairman who died during the year was Dwight E. Perrine, chairman of Committee 6—Buildings, who passed away in the second year of his term as chairman, on September 21, 1958.

The former chairmen who died during the year other than Past President Wiltsee were W. J. Eck, retired assistant to vice president, Southern Railway, who was chairman of Committee 10—Signals and Interlocking, 1921–1923; and L. H. Laffoley, engineer of hotels, Canadian Pacific, who was chairman of Committee 6—Buildings, 1939–1942.

Among the others who died during the year was W. M. Wilson, emeritus professor of structural engineering, University of Illinois, who, as a member of Committee 15—Iron and Steel Structures, from 1924 through 1954, and as a member of Committee 30—Impact and Bridge Stresses, from 1930 through 1954 (a Member Emeritus of both committees at the time of his death), made many significant contributions to the work of the Association regarding structures. Some of the more important of these had to do with bridge rollers, high-strength bolts for structural joints, and welded joints for bridges.

ACTIVITIES OF COMMITTEES

Membership on Committees

Reflecting the continued interest of members in serving on committees—and of the railroads in being represented on committees—is the record of committee membership during 1958, which shows that, in spite of a considerable turnover in the rosters of the various committees, a few more members served on committees than in the immediately preceding year.

Specifically, on February 1, 1958, 1125 members (including 57 Members Emeritus) were serving on the Association's 23 standing and special committees, occupying a total of 1246 places on these committees. This compares with the 1114 members who occupied 1247 places on these same committees as of February 1, 1957. That interest in membership on committees continues to be sustained, is seen further in the fact that as of February 1, 1959, 1125 members were serving in 1246 places on committees—exactly the same as on February 1, 1958.

In addition to their regular members, practically all committees carried "guest" members on their rosters—members awaiting definite assignment to the committees with the official roster change to become effective at the time of the 1959 convention, but who were permitted to participate unofficially in committee work. Also, many committee meetings were attended by "visitors", with the permission of the chairmen. These visitors included retired members, interested outsiders, and members of the Association generally, who, for one reason or another wished to participate in specific meetings or in inspections made in connection therewith.

The turnover of memberships on committees as a whole as of the end of 1958 amounted to approximately 10 percent, compared with slightly in excess of 13 percent in the previous year. The turnover as of the end of 1958 was brought about by the addition of 130 new members on committees and the deletion of 130 members from committees. The large number of new members involved in this turnover reflects, as indicated earlier, the continuing desire of members and their roads to be represented on committees, while the equally large number of deletions from committee rosters reflects not only the retirement of members from active railroad service and adjustments in personnel on the railroads, as well as changes in the interests of members, but also the result of the Board rule in effect that committee members who cannot or do not participate actively in committee work by attendance, correspondence, and the regular execution of letter ballots, must be dropped from committee rosters. However, that this latter was not an important factor during the past year, in spite of the augmented regular responsibilities of nearly all members, is seen in the fact that only 21 members were dropped from committees for this cause.

Work of Committees

Working through subcommittees, the work of committees during 1958 again followed much the same pattern as in previous years, the different subcommittees carrying out their own studies and investigations independently, or working with or through the research staff of the Association of American Railroads, to the end of preparing progress or final reports for information; of revising material appearing in the Association's Manual of Recommended Practice and Portfolio of Trackwork Plans to improve or bring it up to date; of developing new Manual and Portfolio material; and of carrying out special projects related to their assignments. That there was no let-up in the work of committees during the year, in spite of handicaps encountered, is seen in the fact that they produced one or more reports on 142 of their 190 assignments, 24 of which were final reports.

The interest of committees in keeping their Manual material up to date is reflected in the fact that 13 of the Association's 21 committees which have chapters in the Manual included Manual recommendations in their reports for the year, to be acted upon at the 1959 convention.

Classification of Material Produced by Committees

Following is a general categorical classification of the work produced by the committees during the year, as published in the Bulletins of the Association, to be presented to the 1959 convention:

Recommendations pertaining to the development, revision, or reapproval without change, of 50 specifications and uniform practices for inclusion in the Manual; 80 reports on current developments in engineering practice and design; 15 reports dealing with economy in the use of labor and the recruiting and training of employees; 7 reports on new and improved power tools, machines, materials and equipment; 3 reports involving statistics; 8 economic and analytical studies; 5 reports on relations with public authorities; and 4 bibliographies.

The work of the committees affecting the Manual included the presentation of 2 specifications for adoption; the revision of 10 specifications (with or without reapproval); the reapproval of 6 specifications without change; the presentation of 1 tentative specification; tentative revisions in 1 specification; the presentation of 4 recommended practices for adoption; the deletion of 1 recommended practice; the revision of 9 recommended practices, with or without reapproval; the reapproval of 8 recommended practices without change; the presentation of 2 tentative recommended practices; the presentation of 1 agreement form for adoption, the revision of 1 agreement form; and the presentation of 1 tentative agreement form. In addition, instructions with regard to three machines were presented for inclusion in the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment.

Work on new or revised Trackwork Plans during the year resulted in the presentation of 1 new plan for adoption, 2 revised plans, 6 appendix sheets, and 3 contents sheets. However, it also called for minor revisions in 33 plans to bring them into harmony, employing an ingenious method developed by the committee to record these changes in the Portfolio for the benefit of users, without the necessity of reissuing these plans. Briefly, this method involves a new Errata Section in the Table of Contents of the Portfolio, with a direct tie-in to the specific plans affected through the medium of asking the holders of the Portfolio to add a hand-lettered suffix to the numbers on these plans until such time as they are reissued in revised form. A description of this expedient appears in the report of Committee 5—Track, as published in Bulletin 549 for February 1959.

Careful Screening of Committee Assignments

Long before committees had completed their year's work on their current assignments, they were again giving thoughtful consideration to recommendations for new assignments for the coming year, along with assignments to be continued or dropped. This consideration was spearheaded within the different committees under their Assignment A. Recommendations for Further Study and Research, by subcommittees which included in their personnel, in most instances, the vice chairman of the committee and all of the other subcommittee chairmen. Through the stimulus given to the matter of assignments by these subcommittees, nearly every committee developed more suggestions for new subjects than it was feasible for them to undertake, making it necessary for them to sift their suggestions down to a practical number to recommend to the Board for approval. Following this procedure, a total of 36 new subjects were assigned to the 23 standing and special committees of the Association for investigation in 1959, including 2 assignments, encouraged by the Board, to give emphasis to the matter of simplification and standardization—especially in the matter of special trackwork and rail sections.

At the same time, 32 of the 190 assignments of committees in 1958 were dropped, and 158 were continued, with the net result that, for the 1959–1960 Association year, the committees as a whole have a total of 194 assignments (not including Assignments A).

Continued Close Liaison Between Board and Committees

While economic conditions made it inadvisable for the Board to arrange a meeting of all committee chairmen early in the year with the officers of the Association and the chairmen of the different Board committees, to review committee procedures, iron out inter-committee problems, and answer any questions in the minds of chairmen, the Board did keep in close touch with the work of committees throughout the year, continuing practices established in the immediately preceding two years. One of these is that of having one of the officers or directors of the Association sit in, as a guest, at at least one meeting of each committee during the year, with a prearranged opportunity for them to present the thinking of the Board on current Association matters and to receive suggestions from the committees. Another was careful scrutiny of the activity record of committee members through the Committee Member Activity Charts maintained by all chairmen, which were turned in for review by the Board early in October, in connection with the reassignment of members to committees for 1959.

Committee Meetings

Reflecting the request of the Board of Direction, some fewer meetings of committees were held during the year ended March 1, 1959, a larger number were held centrally in the country—especially Chicago—and many of them were confined to a single day. However, with the distinctly improved economic conditions at the turn of the new year, 10 committees held meetings in January and February 1959 in order to get reorganized and an early start on their new year's work. A considerable number of committee meetings throughout the year were supplemented by inspection trips to see facilities, structures, or practices directly related to the work of committees, but, again, reflecting the admonition of the Board of Direction, practically none of these trips had the effect of extending the committee meetings an extra day.

Specifically, 66 full meetings were held during the year ended March 1, 1959. This compares with 73 meetings held during the year ended March 1, 1958, and with 70 during the year ended March 1, 1957. Of the 66 meetings held during the 1958–1959 Association year, 48 were held in Chicago, 2 were held at New Orleans, and 16 were held in as many different cities, for the most part centrally in the country or elsewhere most convenient to the members of the committees. The 48 meetings held in Chicago during the year, which included 15 meetings and luncheons held during the 1958 convention, compares with 30 held in Chicago the previous year.

RESEARCH WORK

In 1958, due to recession conditions, with resulting restricted railroad earnings, the extent of the research activities of the Association, sponsored by its committees and carried out by or through the Engineering Division research staff of the AAR, was a matter of uncertainty almost from the beginning of the year. However, despite conditions, a large amount of research work was carried forward, which, expenditurewise, exceeded that in any previous year.

Late in 1957, viewing the prospects for 1958 optimistically, the AAR Board of Directors approved an Engineering Division Research Budget in 1958 in the amount

of $570,609, and still later in that year authorized work on two additional new projects, to the extent of $45,000, to be paid for from unexpended research funds in 1957. One of these was to investigate the possibility and practicability of the brazing, or diffusion bonding, of rails together to produce multiple lengths, or to provide closure welds between stretches of continuous welded rail in track. The other involved feasibility studies on nuclear light sources, especially for illuminating certain types of roadway signs. In addition, in January 1958, authorization was received to carry over $160,000 of unexpended funds to pay for equipment for the new Engineering Laboratory at the AAR Research Center, ordered in 1956 and 1957, but not delivered.

But, in the light of continuing unfavorable economic conditions, by February 1958 the AAR found it necessary to reappraise its entire operations as contemplated for 1958, including its research program, which resulted in a delayed start on some of the engineering research projects contemplated, and deferring work on some other projects. However, the record for the year shows that, in addition to the expenditures for equipment for the Engineering Laboratory, $563,709 were expended on engineering research sponsored by AREA committees and the AAR Joint Committee on Relation Between Track and Equipment.

For 1959, AREA committees and the AAR Joint Committee proposed research work which would have called for a total expenditure of $684,000. However, in its careful review of the various projects proposed, the AREA Board of Direction, recognizing the probable inability of the AAR to finance an engineering research program of this size in 1959, submitted to the AAR a budget calling for a total expenditure of $586,550. This proposed budget presented the various research projects in two groups as to priority—Group A, which included projects which the Board felt must be undertaken or continued in 1959, and Group B, which included projects which it felt should be undertaken or continued, but the appropriation for which might be reduced if necessary.

In addition, the budget presentation listed a number of other committee-proposed projects, previously started or new, which the Board stated it would like to see undertaken in 1959 if funds could be made available. The amount of money involved in these additional projects amounted to $54,250.

On November 21, 1958, the Member Roads of the AAR tentatively approved a 1959 engineering research budget in the amount of $559,550, $27,000 less than the amount requested, with the understanding that final approval would await the results of a review of the activities of the Research Department, AAR, and its related budget allotment, by a committee of the AAR Board of Directors.

As this report is being written, the "review" by the appointed committee is still under way and no final action has been taken with respect to the 1959 budget. However, pending such action, the research work on engineering projects continues apace, subject to any adjustment or modification which may subsequently be called for.

The accompanying tabular material shows the total allotments for research under the direction of the Engineering Division, AAR, 1942–1958, incl. It also presents a summary of projects included in the 1959 Engineering Division Research Budget, showing expenditures for each project as authorized tentatively by the AAR, compared with amounts requested, and with estimated expenditures on these projects in 1958.

TOTAL ALLOTMENTS FOR RESEARCH WORK, ENGINEERING DIVISION, AAR, 1942–1959

1942	$ 87,932	1951	354,770
1943	98,445	1952	381,400
1944	109,050	1953	364,100
1945	138,110	1954 (as modified)	351,307
1946	159,510	1955	351,653
1947	234,428	1956	365,050
1948	291,840	1957	476,845
1949	372,457	1958	563,709
1950	294,045	1959 (tentative)	559,550

SUMMARY OF PROJECTS INCLUDED IN 1959 ENGINEERING DIVISION RESEARCH BUDGET, APPROVED TENTATIVELY BY THE AAR, SHOWING EXPENDITURES AUTHORIZED FOR EACH PROJECT, COMPARED WITH AMOUNTS REQUESTED, AND ESTIMATED EXPENDITURES ON THESE PROJECTS IN 1958

Administration	*1958 Estimated Expenses*	*1959 Budget Request*	*1959 Budget*
Research Office	$ 62,759	$ 59,400	$ 59,400
Total	$ 62,759	$ 59,400	$ 59,400
Committee 1—Roadway and Ballast			
Roadbed Stabilization	$ 29,300	$ 29,900	$ 29,900
Ballast Tests	19,300	16,700	16,700
Chemical Vegetation Control	16,300	17,200	17,200
Nuclear Light Sources	15,000	0	0
Performance of Filter Materials in Subdrains	3,000	0	0
Erosion Control for Outlet Structures	3,100	0	0
Total	$ 86,000	$ 63,800	$ 63,800
Committee 3—Ties			
Anti-Splitting Devices for Ties	$ 10,000	$ 12,000	$ 12,000
Tie Coatings	2,500	2,500	2,500
Service Tests of Laminated Ties and Combined Seasoned and Treated Ties	1,000	1,000	1,000
Total	$ 13,500	$ 15,500	$ 15,500
Committee 4—Rail			
Transverse Fissure Investigation	$ 6,350	$ 6,350	$ 6,350
Shelly Spots and Head Checks	15,650	15,650	15,650
Rail Failure Statistics	10,550	10,550	10,550
Rail Design Investigation	4,300	4,300	4,300
Rolling Load Tests of Joint Bars	15,000	16,300	16,300
Welding Battered Rail Ends	14,700	15,400	15,400
Tests with 78-ft Rail	2,000	4,500	4,500
Service Tests of Joint Bars	3,550	0	0
Total	$ 72,100	$ 73,050	$ 73,050
Committee 5—Track			
Tie Plate Design	$ 0	$ 3,800	$ 3,800
Bolt Tension and Rail Joint Lubrication	4,300	4,500	4,500
Corrosion from Brine Drippings	15,500	20,000	16,000
Manganese Frog Design	11,650	13,400	13,400
Laying Rail Tight with Frozen Joints	4,800	5,900	5,900

	1958 Estimated Expenses	1959 Budget Request	1959 Budget
Welding Frogs and Switches	7,100	6,900	6,900
Tie Plate Fastenings	19,300	20,500	20,500
Total	$ 62,650	$ 75,000	$ 71,000
Committee 6—Buildings			
Wind Loads	$ 4,000	$ 4,000	$ 4,000
Total	$ 4,000	$ 4,000	$ 4,000
Committee 7—Wood Bridges and Trestles			
Timber Stringer Tests	$ 5,200	$ 6,200	$ 6,200
Timber Bearing Tests	5,700	5,700	5,700
Fire Retardant Coatings	13,000	15,000	13,000
Preparation of Standard Bridge Plans	1,000	2,000	2,000
Laminated Girders	0	5,200	5,200
Total	$ 24,900	$ 34,100	$ 32,100
Committee 8—Masonry			
Concrete Deterioration	$ 12,400	$ 12,400	$ 12,400
Reinforced Concrete Research Council	4,000	6,000	5,000
Bearings for Concrete Bridges	3,000	3,000	3,000
Scour Around Foundations	2,500	5,000	5,000
Total	$ 21,900	$ 26,400	$ 25,400
Committee 9—Highways			
Grade Crossing Protection Study	$ 0	$ 10,000	$ 10,000
Total	$ 0	$ 10,000	$ 10,000
Committee 15—Iron and Steel Structures			
Model Bridge Tests	$ 10,500	$ 10,500	$ 10,500
Riveted and Bolted Structural Joints	8,000	10,000	8,000
Steel Structures Painting Council	8,000	10,000	8,000
Welding Research—Structures	0	10,000	8,000
Corrosion of Deck Plates	3,000	3,000	3,000
Total	$ 29,500	$ 43,500	$ 37,500
Committee 17—Wood Preservation			
Termite Control Investigation	$ 1,000	$ 5,000	$ 5,000
Total	$ 1,000	$ 5,000	$ 5,000
Committee 29—Waterproofing			
Bituminous Waterproofing and Dampproofing Materials	$ 5,200	$ 7,200	$ 7,200
Membrane Waterproofing Materials	8,100	8,100	8,100
Total	$ 13,300	$ 15,300	$ 15,300
Committee 30—Impact and Bridge Stresses			
Bridge Impact Studies	$ 84,700	$ 80,000	$ 80,000
Prestressed Concrete Beams	0	11,000	11,000
Distribution of Axle Loads	6,200	0	0
Deflection and Depth Ratios of Bridges	8,200	15,500	10,500
Electronic Calculation of Bridge Stresses	12,000	12,000	12,000
Total	$111,100	$118,500	$113,500

	1958 Estimated Expenses	1959 Budget Request	1959 Budget
Joint Committee Relation Between Track and Equipment			
Relation of Wheel Load to Wheel Diameter	$ 7,000	$ 25,000	$ 20,000
Clearance Requirements	9,000	10,000	10,000
Ride Comfort—New Type Passenger Train Versus Conventional Equipment	4,500	0	0
Wheel Slippage on Axle from Lateral Thrust	2,500	3,000	3,000
Signal Shunting by Motor Cars and Lightweight Equipment	2,000	0	0
Tracking Tests of Trainmaster Locomotives	3,000	0	0
Rolling Resistance of Freight Cars	3,000	0	0
Total	$ 31,000	$ 38,000	$ 33,000
Board Committee on Research			
Long-Range Weather Forecasting	$ 0	$ 5,000	$ 1,000
Total	$ 0	$ 5,000	$ 1,000
Special Committee on Continuous Welded Rail			
Brazing of Rails	$ 30,000	0	0
Total	$ 30,000	0	0
Grand Totals	$563,709	$586,550	$559,550

PUBLICATIONS

The seven monthly Bulletins of the Association ending with the February 1959 issue contain 1222 pages of text matter and illustrations, exclusive of advertising, and 16 inserts of one kind or another. Reflecting primarily more concise report writing, prompted by the desirability of holding down publication costs, this is a fewer number of Bulletin pages than during the previous two years—1324 pages and 1349 pages, respectively. The committee reports published for presentation at the 1959 Annual Meeting occupied 768 pages in Bulletins 546 to 549, incl. This is 70 pages more than were devoted to committee reports in comparable Bulletins the previous year, an increase which was occasioned in large part by the larger number of reports made on committee assignments during the past year.

To the number of Bulletin pages devoted to committee reports during the past year should be added the 208 pages of reports on research projects sponsored by AREA committees, or groups in which AREA committees are interested, which appeared in Bulletins 544 and 545, for June–July and September–October 1958. These 208 pages in the two "summer" Bulletins of 1958 compare with 388 pages devoted to the same type of reports in the "summer" Bulletins of the previous year.

The Annual Supplement to the Manual issued in 1958, incorporating all of the recommendations of committees affecting Manual material adopted at the 1958 Annual Meeting, included a total of 104 sheets. At the same time, it called for the removal of 85 existing Manual sheets, leaving a net gain of 19 sheets in the Manual as revised. The 104-page Manual Supplement in 1958 compares with the 147-page Manual Supplements in 1957, and with the 102-page Supplement issued in 1956.

The Annual Supplement to the Portfolio of Trackwork Plans issued in 1958 was again very limited in size, including only 6 sheets. This small Supplement, and the fact that there were only 4 sheets in the 1957 Supplement, and no Supplement to the

Portfolio was issued in 1956, resulted from the practically complete revision of the entire Portfolio in 1955. The 6 sheets in the 1958 Supplement included 2 plans, 2 appendix sheets covering revisions in the AREA Specifications for Special Trackwork, and 2 Table of Contents sheets.

In July 1958, the secretary's office completed and started mailing to holders of the Manual a 12-page General Subjects Index of the Manual, completely up to date as of the 1958 Supplement.

Essentially, the new General Subjects Index is a summation of the present Chapter Tables of Contents, but with subjects arranged in alphabetical order, and including reference also to the basic items in the Portfolio of Trackwork Plans.

No revisions will be made in the new General Subjects Index between reprintings of the Manual (approximately every five years). However, it is planned to print and distribute with each Annual Supplement to the Manual a cumulative addendum (one or two sheets) containing required changes in the Index, with items arranged in alphabetical order.

With each reprinting of the Manual (to replenish the supply for sale), the General Subjects Index will be recast to absorb all addendum items since the previous reprinting, and enough copies will be run off for distribution free to all then holders of the Manual, and for the reprinted copies of the Manual which will be held in stock for future sale.

Engineer Recruiting Brochure

One of the outstanding publication efforts of the Association during the year, although not completed for distribution, was the revision by Committee 24—Cooperative Relations with Universities, of its Engineer Recruiting Brochure entitled "The Railroad Field—A Challenge and Opportunity for Young Engineers". It will be recalled that the first edition of this brochure was published in 1955 with a press run of 25,000 copies, and was distributed free throughout 1955, 1956 and 1957 to the engineering colleges of the United States and Canada, and to a large number of high school counselors, as well as in sizable number, at cost, to a large number of railroads for use in their recruiting efforts.

The revision of the text of the earlier edition, which was intended to make the new edition even more attractive, definitive, informative, and convincing, was completed late in the fall, with the hope that copies of the new edition would be available for distribution early in 1959. In fact, the Board of Direction, at its August meeting, in anticipation of early completion of the text and early publication, authorized the printing of 28,000 copies—18,000 for distribution by the Association during 1959, 1960, and 1961, and 10,000 copies to cover an order from the School and College Service of the Public Relations Department of the Association of American Railroads for its distribution over a similar period.

But practical considerations, including the collection of a large number of photographs from which to select new illustrations for the brochure, the taking of bids for printing, and the unusually heavy load on the secretary's office throughout the fall and winter months in publishing committee reports and preparing for the 1959 Annual Convention, made early 1959 publication of the new edition impossible. In view of this, printing of the new edition has been postponed until the summer months of 1959, looking to distributing copies to the colleges early in October, just after the beginning of their fall terms.

Student Recruiting Guide

Another notable publication effort of the Association during the year, which, however, like the Engineer Recruiting Brochure, did not reach the general distribution stage, was the text for the first edition of a Student Recruiting Guide—also produced by the Committee on Cooperative Relations with Universities. The guide presents recommended techniques to be used by the railroads in recruiting college and university students, and the committee has proposed it be published in pamphlet form and made available to the railroads to assist them in their recruiting efforts. No doubt, this proposal will be approved by the Board of Direction at one of its two meetings at the time of the 1959 Association convention.

Manual of Convention Arrangements

One other publication of the Association, started late in 1958, and only completed by the secretary's office just prior to the date of this report, deserves mention because of the sizable effort involved and its importance to one aspect of the Association's welfare, even though its distribution is less than 50 copies and is confined to a small specific group within the Association membership. This is the completely revised edition of the Manual of the Association's Committee on Convention Arrangements, a document including 45 single-spaced typewritten pages, in a flexible binder, which sets forth in minute detail all of the duties and responsibilities of the committee as a whole and of its eight subcommittees. Whereas the last previous edition, revised in 1955, was built around Association conventions as held at the Palmer House, Chicago, and convention activities as of that time, the new edition spells out the duties and responsibilities of every assignment within the committee under present convention practices and procedures, and is, for the most part, applicable regardless of the hotel in which the convention may be held.

Distribution of Publications

In the Calendar Year 1958 the Association continued widespread distribution of its publications over and above those going to its own large membership. This distribution totalled approximately 30,200 copies, 27,300 of which were sold from the secretary's office to, among others, the American railroads, colleges and universities, students, Government agencies, engineers in industry generally, and railroad men in foreign countries. The remaining 2900 copies included approximately 400 copies of the Engineer Recruiting Brochure sent out free to engineering colleges, universities and high school counselors from the secretary's office, and approximately 2500 reprints of research reports published by the AREA, which were made available to the AAR research staff.

The 30,200 copies of publications distributed during 1958 was 8300 copies fewer than the number distributed in 1957, a difference which reflects, on the one hand, the fact that approximately 8600 fewer copies of the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment were sold in 1958, and that, due to a depleted supply, only about 400 copies of the Engineer Recruiting Brochure were available for distribution in 1958, compared with a distribution of 3675 copies in 1957. On the other hand it reflects an increase in the sale of approximately 3575 copies of other Association publications.

Large as was the distribution of publications in 1958, it was somewhat smaller than it might have been in view of the continued refusal on the part of the Association to fill many foreign orders received which were not given clearance by the Office of International Trade at Washington, D. C.

Following is a tabulation of the publication sales made in 1958.

SALES OF ASSOCIATION PUBLICATIONS—1958

Specifications (Bridge)	1,380
Manual chapters	1,387
Manual specifications and partial chapters	1,369
Manual specifications, large orders (more than 100)	13,500
Bulletins	1,671
Bulletin reprints	481
Special reprints in large orders (100 or more)	4,250
Proceedings	167
Consolidated Proceedings indexes	12
Revisions to Manual	880
Manuals (complete) and separate fillers	192
Revisions to Portfolio of Trackwork Plans	966
Complete Portfolios of Trackwork Plans	96
Individual track plans	730
Federal Valuation of Railroads	14
Achievement of Grade Crossing Protection	2
J. A. Given booklets	21
Engineer recruitment brochure	100
Maintenance of Way Equipment Handbooks	71
	27,289

FINANCES

The Report of the Treasurer, Financial Statement, General Balance Sheet, and Statement of Cash Receipts and Disbursements for the calendar year 1958, all of which are presented herein, indicate that the Association continues in a sound financial condition, with total Receipts for the year exceeding Disbursements by $4105.64, and with the total assets of the Association some $1500 higher, compared with 1957. A comparison of Receipts and Disbursements for the past two years is presented below:

	1957	*1958*
Receipts	$85,429.31	$81,454.56
Disbursements	89,830.57	77,348.92
	—$ 4,401.26	$ 4,105.64

The following reviews briefly the financial picture for the year. In the first place, Receipts for 1958 were lower than those of 1957 by $3975. This resulted primarily from a combination of smaller Receipts in some accounts in 1958, compared with 1957, on the one hand, and, on the other hand, sizable Receipts in two new accounts in 1958, both related to the 1958 convention. More specifically, whereas only $59 was realized from the sale of the revised edition of the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment in 1958, Receipts from the sale of this publication amounted to $6420 in 1957, when the revised edition was issued. At the same time, Receipts from Convention Registration Fees in 1958, the first year such fees were charged, totaled $2605, while an additional $792 was realized from the sale of tickets to the ladies' luncheon at the South Shore Country Club during the 1958 convention, for which there was no paralleling credit for 1957. These two new credit items alone in 1958, totaling $3397, offset much of the higher Receipts in 1957.

It is gratifying that the total Receipts in 1958 were as high as they were in view of the general low level of business activity during at least the first two-thirds of the year—receipts which were actually some $5000 higher than were anticipated at the beginning of the year.

Total Disbursements in 1958 amounted to $77,348.92, $12,730 under those for 1957. This decrease reflects, on the one hand, an abnormal expenditure in 1957 of $7405 for printing the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment, and $10,800 for reprinting 1200 Manual fillers to replace a depleted supply. On the other hand, it reflects larger expenditures for certain items in 1958 over 1957, in the amount of $5524. These latter items include $1325 for the purchase of a supply of certain Manual Chapters for individual Chapter sales; $2318 increased charges against the item of Convention Expenses; an increase of $1243 in the item of Salaries; an increase of $438 in normal Postage Expense; and an item of $200 for Brochure-Mailing Postage. In view of this situation, it is evident that the total of all other Disbursements approximated those in 1957.

It is well that the Association enjoyed a good year financially in 1958, with an excess of Receipts over Disbursements of $4105, if only to offset almost in its entirety the deficit of $4401 in 1957. In fact, it is especially fortunate that the Association realized this offsetting profit in 1958, since it is expected that, even with generally favorable conditions in 1959, the Association will incur a deficit in that year of some $8000 due to increased costs for printing, salaries, postage, office rental, and the publication of a three years' supply of the revised Engineer Recruiting Brochure.

Comparison of Receipts and Disbursements for a 20-Year Period

	Receipts	*Disbursements*	*Net Gain*
1939	$28,189.00	$23,847.00	$ 4,342.00
1940	28,272.00	26,451.00	1,821.00
1941	32,433.00	29,384.00	3,049.00
1942	31,500.00	26,692.00	4,808.00
1943	28,736.00	23,809.00	4,927.00
1944	30,492.00	26,534.00	3,958.00
1945	32,305.00	29,305.00	3,000.00
1946	28,836.00	34,583.00	5,747.00*
1947	46,993.00	46,989.00	4.00
1948	57,741.00	53,062.00	4,679.00
1949	62,081.00	57.075.00	5,005.00
1950	59,752.00	51,795.00	7,957.00
1951	69,045.00	62,369.00	6,676.00
1952	77,514.00	76,964.00	550.00
1953	73,033.07	82,067.86	9,034.79*
1954	85,748.99	68,003.03	17,745.96*
1955	80,177.21	73,923.18	6,254.03
1956	79,531.11	70,336.17	9,014.94
1957	85,429.31	89,830.57	4,401.26*
1958	81,454.56	77,348.92	4,105.64

* Deficit.

The foregoing report clearly bears out, I am sure, the statement at the outset of this report, that in 1958, despite the generally unfavorable conditions which prevailed, the Association retained the interest of its members, continued its work unabated, closed the year in a favorable financial condition, and moved generally into higher ground, with the single exception of total membership—a significant achievement. Continuing the same general policies, with some emphasis on recouping the membership loss of the past year, there is every reason to expect that the Association will move forward to a still higher level of well-being and achievement in the year ahead.

Respectfully submitted,

Neal D. Howard,
Executive Secretary.

Deceased Members

F. T. Beckett

Retired Assistant Chief Engineer, Chicago, Rock Island & Pacific Railroad, Sapulpa, Okla.

K. A. Begemann

Instrumentman, Missouri Pacific Railroad, Little Rock, Ark

H. I. Benjamin

Retired Vice-Chairman, System Committee on Insurance, Southern Pacific Company, San Francisco, Calif.

W. H. Brameld

Retired Assistant to Chief Engineer, Maintenance of Way, Erie Railroad, Paterson, N. J.

C. B. Breed

Professor Emeritus of Civil Engineering, Massachusetts Institute of Technology
Harbor Road, Camden, Me.

H. C. Charlton

Assistant Engineer Bridges, Norfolk & Western Railway, Roanoke, Va.

A. Chinn

President, Terminal Railroad Association of St. Louis, St. Louis, Mo.

A. C. Clarke

Retired Chief Engineer, Baltimore & Ohio Railroad, Porpoise Point, Vero Beach, Fla.

J. E. Crawford

Retired Vice President—Assistant to President, Norfolk & Western Railway, Roanoke, Va.

A. M. Currier

Retired Assistant to Vice-President, New York Central System, Cleveland, Ohio

J. E. Deckert

Director, Deckert Corporation, Morton Grove, Ill.

M. M. Dutra

care Estrada de Ferro Santos a Jundiaf, Rua Desembargador Guimaraes No. 72,
Sao Paulo, Brazil, S. A.

W. J. Eck

Retired Assistant to Vice-President, Southern Railway System, Arlington, Va.

O. W. Eshbach

Professor of Engineering Science, Northwestern Technological Institute, Evanston, Ill.

L. P. O. Exley

Retired Chief Engineer, Gulf, Mobile & Ohio Railroad, Miami Beach, Fla.

W. A. Fisher

Retired Secretary, Bernuth, Lembcke Company, Inc., Bound Brook, N. J.

D. Z. Gardner, Jr.

Division Engineer, Atchison Topeka & Santa Fe Railway, Los Angeles, Calif.

A. Hazen

Assistant Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Minneapolis, Minn.

W. B. HODGE
Retired Division Engineer, New York Central System, Indianapolis, Ind.

O. W. IRWIN
President, Rail Steel Bar Association, Chicago, Ill.

M. F. JAEGER
Superintendent, Port Reading Creosoting Plant, Reading Company, Central Railroad of New Jersey Port Reading, N. J.

P. M. LABACH
Los Angeles, Calif.

L. H. LAFFOLEY
Engineer of Hotels, Canadian Pacific Railway, Montreal, Que.

J. W. LASHER
Armco Drainage & Metal Products, Inc., Duluth, Minn.

F. J. LEWIS
Dean, School of Engineering, Vanderbilt University, Nashville, Tenn.

F. H. MASTERS
Retired Special Engineer, Elgin, Joliet & Eastern Railway, Joliet, Ill.

N. W. MCCALLUM
Retired Chief Engineer, Pittsburgh & Lake Erie Rallroad, Scarsdale, N. Y.

T. H. MCKIBBEN
Retired Assistant Chief Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

G. A. MCROBERTS
Division Engineer, Southern Railway System, Somerset, Ky.

H. F. PASSEL
Retired Division Engineer, Baltimore & Ohio Railroad, Indianapolis, Ind.

D. E. PERRINE
Assistant Chief Engineer, Chicago & Western Indiana Railroad, Chicago, Ill.

F. A. POLING
Division Engineer, New York, Chicago & St. Louis Railroad, Brewster, Ohio

J. W. PORTER
Retired Chief Engineer Western Region, Canadian National Railways, Winnipeg, Man.

G. W. RATHJENS
Consulting Engineer, Berkeley, Calif.

M. D. SALINGER
Chief Engineer, Cleveland Frog & Crossing Co., Cleveland, Ohio

L. D. SHELKEY
Assistant Engineer, Bessemer & Lake Erie Railroad, Greenville, Pa.

P. T. SIMONS
Retired Assistant Engineer, Missouri Pacific Lines, St. Louis, Mo.

A. L. SIMPSON
Timber Treatment Engineer, New York Central System, Toledo, Ohio

E. D. SWIFT
Retired Engineer Maintenance of Way, Belt Railway, Chicago, Ill.

F. C. TESKE, JR.
Assistant to Chief Engineer, Minneapolis, St. Paul & Sault Ste. Marie Railroad, Minneapolis, Minn.

W. H. VANCE
Retired Assistant Engineer Maintenance of Way, Missouri Pacific Railroad, Louisville, Ky.

C. P. VAN GUNDY
Retired Engineer of Tests, Baltimore & Ohio Railroad, Aberdeen, Md.

W. M. WILSON
Emeritus Research Professor of Structural Engineering, University of Illinois, Urbana, Ill.

W. P. WILTSEE
Retired Chief Engineer, Norfolk & Western Railway, Roanoke, Va

A. H. WOERNER
Retired Superintendent, Baltimore & Ohio Railroad, Washington, Ind.

J. C. WOODS
Chief Engineer, St. Johnsbury & Lamoille County Railroad, Montpelier, Vt.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1958

Balance on hand January 1, 1958		$145,664.57

RECEIPTS

Membership Account		
Entrance Fees	$ 1,560.00	
Dues	42,905.96	$44,465.96
Sale of Publications		
Proceedings	1,531.23	
Bulletins	2,435.75	
Manuals	8,657.27	
Specifications	1,642.31	
Track Plans	1,536.40	
Research Reports	6,257.04	22,060.00
Advertising		
Publications		6,953.70
Interest Account		
Interest on Investments		3,705.94
Miscellaneous		
Registration (Convention)	2,605.00	
Luncheon Receipts (Ladies)	792.00	
Other	849.01	4,246.51
Total		$81,432.11

DISBURSEMENTS

Salaries	$25,526.96	
Proceedings	14,207.39	
Bulletins	14,238.97	
Stationery and printing	2,039.72	
Rent, light etc.	1,140.00	
Supplies	377.85	
Postage	2,153.11	
Audit	400.00	
Pensions	300.00	
Social security, unemployment tax and insurance	1,061.40	
Manual	6,451.43	
Track plans	183.95	
Committee and officers expense	383.12	
Annual meeting expense	4,910.97	
News letter	2,832.88	
Miscellaneous	1,141.17	
Total		$77,348.92
Excess of Receipts over Disbursements		4,083.19
Profit on Exchange of securities		22.45
Balance on hand December 31, 1958		$149,770.21

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1958		$145,664.57
Receipts during 1958	$ 81,432.11	
Paid out on audited vouchers	77,348.92	
Excess of receipts over disbursements	4,083.19	
Profit on exchange of bonds	22.45	4,105.64
Balance on hand December 31, 1958		$149,770.21
Consisting of bonds at cost	148,835.39	
Cash in Northern Trust Company Bank	909.82	
Petty cash	25.00	$149,770.21

We have made an examination of the accounts of The American Railway Engineering Association for the year ended December 31, 1958, and found them to be in accordance with the foregoing statement.

C. A. Bick,
P. D. Mitchell,
Auditors.

GENERAL BALANCE SHEET

Assets:	*1958*	*1957*
Due from members	$ 66.00	$ 48.00
Due from sale of publications	98.50	131.20
Due from sale of advertising	956.40	1,147.80
Prepaid postage	23.81	51.95
Furniture and fixtures	1,345.00	1,495.00
Inventories:		
Publications (estimated)	500.00	500.00
Manuals	7,917.00	8,080.00
Track Plans	1,154.50	1,852.50
Binders, index and chapter	95.00	92.00
Paper stock	—	1,344.00
Investments (cost)	148,835.39	143,887.89
Interest accrued on investments	432.19	402.82
Cash in Northern Trust Company Bank	909.82	1,751.68
Petty cash	25.00	25.00
Totals	$162,358.61	$160,809.84
Liabilities:		
Members dues paid in advance	$ 372.00	$ 631.29
Surplus	161,986.61	160,178.55
Totals	$162,358.61	$160,809.84

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS YEAR 1958

Cash in Bank, January 1, 1958		$ 1,751.68
Receipts:		
From members, sales of publications, interest, etc.		81,732.11
From sale of securities		12,963.08
		$ 96,446.87
Disbursements:		
Audited vouchers	$ 77,648.92	
Securities purchased	17,888.13	95,537.05
Cash in Bank, December 31, 1958		$ 909.82

American Railway Engineering Association

CONSTITUTION

Revised to October 30, 1958

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Study and Research Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereto, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of his regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of his regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ or in the employ of a consulting engineering organization, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member or an Associate who has paid dues for 35 years, or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. Associate

An Associate shall be:

(a) An engineer of a railway which is essentially an adjunct of an industry, or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than 21 years of age and shall be an engineering employee of a railway corporation who has had not less than three years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 30 years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Assocition and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be required for Junior Membership, except that a Junior Member, in transferring to another class of membership, shall pay the entrance fee prescribed for other classes of Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $15.

(b) The annual dues for each Junior Member shall be $5.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction.

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Executive Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, twelve Directors, an Executive Secretary and a Treasurer.

(b) The President, the Vice Presidents and the Directors, together with the two latest living Past Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice Presidents and the Directors shall be Members.

(c) The Executive Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

2. Method of Nominating

(a) Prior to December 1 of each year the chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Secretary not later than December 15 of the same year, and the Executive Secretary shall report the names of these nominees to the members of the Association not later than January 1 following.

(c) At any time between January 1 and February 1 any ten or more Members may send to the Executive Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, his name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each annual convention, the Executive Secretary shall issue a ballot to each voting Member of record who has paid his dues to or beyond December 31 of the previous year, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in this Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Executive Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and cast another, at any time before the polls close.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote, shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon on the second day of the annual convention, and the ballots shall be counted by tellers appointed by the presiding officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual convention shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

2. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

3. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

4. Executive Secretary

The Executive Secretary, under the direction of the President and Board of Direction shall be the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and record the proceedings thereof. The Executive Secretary shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. He shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee and approved by the Board of Direction, with notification to the Treasurer of such investments. The Executive Secretary shall conduct the correspondence of the Association, make an annual report to the Association, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

6. Board of Direction and Executive Committee

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution.

(b) The Board of Direction shall meet within thirty days after each annual convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the annual convention, the President shall appoint from the membership of the Board, subject to ratification by the Board, four members to serve with him as an Executive Committee which shall possess and may exercise during intervals between meetings of the Board, all of the powers of the Board on matters which in the judgment of a majority of the Executive Committee cannot properly be delayed until the next meeting of the Board. Actions of the Executive Committee shall be reported to the Board of Direction at the next meeting of the Board. The President shall be chairman of the Executive Committee. Actions of the Executive Committee shall be authorized by a concurring majority of its full membership. Members of the Executive Committee shall serve until their successors are appointed or until the Executive Committee is dissolved by action of a majority of the full membership of the Board of Direction. Following dissolution of the Executive Committee it may be re-created at any time by action of a majority of the full membership of the Board of Direction. If not so re-created prior to the next annual convention, the Executive Committee shall be reconstituted in the normal manner at the first meeting of the Board of Direction following the convention.

7. Administrative Committees

At the first meeting of the Board of Direction after the annual convention, the following Administrative Committees, each consisting of not less than three members, shall be appointed by the President. The personnel of these committees shall be subject to approval by the Board of Direction.

Assignments
Finance
Manual
Membership
Personnel
Publications
Research

Other special Administrative Committees may be appointed by the President at any time, and reappointed annually, if necessary, their personnel being subject to approval by the Board of Direction.

Membership on Administrative Committees shall be restricted to members of the Board of Direction, except that one or two members of the Administrative Committee on Research may be past members of the Board of Direction.

8. Study and Research Committees

The Board of Direction may establish continuing or special Study and Research Committees to investigate, consider, and report upon subjects appropriate to the object of the Association, as set forth in Art. I.

9. Duties of Administrative Committees

(a) Assignments

The Assignments Committee shall review and pass upon the recommendations of Association Study and Research Committees for subjects to be investigated, considered and reported on by these committees during the ensuing Association year, and shall

report thereon to the Board of Direction for its approval. The Assignments Committee shall have authority to assign additional subjects or change the scope of any existing subjects at any time during the year, reporting its action thereon to the Board at its next regular meeting.

(b) Finance

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(c) Manual

The Manual Committee, with the assistance of the Publications Committee, shall have general supervision over the Manual.

(d) Membership

The Membership Committee shall investigate applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(e) Personnel

The Personnel Committee shall review and pass upon applications of members for appointment to Study and Research Committees, and shall also appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval. Should an unexpected vacancy in chairmanship or vice chairmanship of any such committee occur, the Personnel Committee shall have authority to fill such vacancy immediately, reporting its action thereon to the Board at its next regular meeting.

(f) Publications

The Publications Committee shall have general supervision over the publications of the Association. The Publications Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(g) Research

The Research Committee shall encourage and coordinate the research activities of the Association, in the course of accomplishment of which it shall review and pass upon the recommendations of Study and Research Committees for research projects and shall report thereon to the Board of Direction, recommending for approval specific projects initiated by these committees or by the Research Committee and recommending allotments of funds for these projects in the research budget of the Association of American Railroads or from other sources compatible therewith; shall collaborate closely with the research staff of the Association of American Railroads; and when called upon by the Vice President—Research or the Vice President—Operations and Maintenance of that association, members of the Research Committee shall engage in the activities of advisory committees or groups of that organization and shall report from time to time to the Board of Direction on those activities.

10. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

11. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

12. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention shall open on the second Tuesday in the month of March, or on the third Tuesday if the month of March has five Tuesdays, excepting that some other opening day in March may be designated by the affirmative vote of two-thirds of the entire membership of the Board of Direction

(b) The Executive Secretary shall notify all members of the Association of the time and place of the annual convention at least 30 days in advance thereof.

(c) The order of business at the annual convention of the Association shall be:

Reading of the minutes of the last meeting
Address of the President
Reports of the Executive Secretary and the Treasurer
Reports of committees
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members, and shall be acted upon in the following manner:

The amendment shall be presented to the Executive Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

Information and Rules for the Guidance of Committees

The following information and rules for the guidance of committees are designed to obtain the maximum benefits from the efforts of the members who make up the personnel of such committees. They are designed to effect a continuity of effort in committee work throughout the entire year, under a plan whereby the personnel of the committees and their respective assignments for investigation and report are set up and made public on or before the beginning of the calendar year, thus enabling the work to be continued without interruption, although the new personnel and subject assignments do not become officially effective until the beginning of the "Association Year," which starts with the close of the annual meeting.

The rules also take into account the fact that the publication of the committee reports must be spread out over a period of four months (November through February), to facilitate printing and to give members of the Association a reasonable length of time in which to study such reports in advance of the annual meeting.

SUBJECT ASSIGNMENTS

Reassigned Annually

The assignments for investigation and report of each committee shall be reviewed annually. To this end, each committee shall review suggestions for new subjects submitted by its Subcommittee A, by other members of the committee, or by others, and such suggestions as receive the approval of the committee shall be submitted by the committee chairman to the executive secretary of the Association not later than October 1. Each suggestion shall be accompanied by brief explanation of the purpose and scope of each proposed assignment, or change in the wording of present assignments. At the same time, the committee chairman shall submit the committee's recommendations covering the withdrawal or continuation of current assignments, with a brief statement of the reason or reasons therefor.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Assignments, which has the responsibility of authorizing the subject assignments to the various committees. Deviations from assignments thus authorized may be made during the course of the year only upon authority of the Board Committee on Assignments. However, this is not to be construed as preventing any committee from proposing additional urgent assignments at any time during the year, upon which it feels work should be begun promptly.

Scope of Assignments of Committees 22 and 27

The scope of assignments of Committee 22 will encompass studies relating to the economics of various types of work equipment as used by the labor forces to which they are assigned, including the labor savings that may be effected, production, and quality of work.

The scope of assignments of Committee 27 will encompass studies involving the mechanical features, operating characteristics, development and maintenance of work equipment, and fuels, lubricants, etc., necessary for its operation; also pertaining to such labor aspects as the selection and training of equipment operators, maintainers and repair forces.

(Revised and amplified November 7, 1958).

Either or both committees may include in their considerations and reports factors of design or operation that affect productivity or quality of work, and such economic aspects as first cost, obsolescence, life, depreciation, and maintenance and repair costs as may be necessary to the comprehensive development of their respective assignments.

In the case of an overlapping assignment, the assignment should normally be handled by the committee principally affected in the light of the foregoing paragraphs, with the other committee collaborating.

COMMITTEE PERSONNEL

Reorganized Annually

The personnel of each committee shall be reorganized annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee, who do not render service by correspondence, or who do not return letter ballots will be dropped. To this end the chairman of the committee shall submit to the secretary's office not later than October 1 the current Committee Member Activity Record Chart, filled out in full regarding each member, and showing in the appropriate columns which members he recommends be dropped because of delinquency in service to the committee, or for other reasons, and those members he recommends be continued on the committee. The chart, at the bottom, should also list any members he recommends for appointment to the committee, whether previously carried as "guest" members or not.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Personnel, which has the duty of appointing the committee personnel.

No additions to the personnel of committees will be made during the year following the official closing of committee rosters, October 1, except as provided for in the rules applying to "Guests."

Members who desire appointment to a committee should make application through the committee chairman or the executive secretary on the prescribed form.

Chairmen, Vice Chairmen and Subcommittee Chairmen

Chairmen, vice chairmen and subcommittee chairmen must hold the grade of Member in the Association, and be in active service of their respective companies or organizations (not retired).

The term of chairman and vice chairman shall be three years in each position, and will normally start at the beginning of the Association year, at the close of an annual meeting. However, the term of office of vice chairman will be shorter if he is appointed to fill a vacancy in the position of vice chairman. Chairmen completing their three-year term shall recommend to the Board Committee on Personnel nominees for the chairmanship and vice chairmanship, with assurance of acceptances from such nominees if appointed by the Board Committee. The term of office of subcommittee chairman may be more than three years.

In the event of a vacancy in the office of chairman, the office shall be filled by the vice chairman, subject to the approval of the Board Committee on Personnel. The three-year term of office of the chairman so approved, or of a new appointee shall be considered as having started as of the end of the immediately preceding convention if the appointment is made prior to the time the committee's report is due in the secretary's office, and as becoming effective as of the end of the next convention if the appointment is made after the committee's report is due in the secretary's office.

In the event of a vacancy in the office of vice chairman, it shall be the duty of the Board Committee on Personnel to fill the vacancy. The term of office of the vice chairman so appointed shall be considered as having started as of the end of the immediately preceding convention if the appointment is made prior to the time the committee's report is due in the secretary's office, and as becoming effective as of the end of the next convention if the appointment is made after the committee's report is due in the secretary's office.

Committee Secretary

Any chairman may appoint a secretary with duties usually encompassed by such office.

Size of Committees*

The total membership of any committee shall be limited to 70, including Members, Associates, and Junior Members, but not counting retired members, even though gainfully employed.

In determining the membership of a committee, railroads having no more than 50 Association members may have not more than 2 members on any committee; railroads having 51 to 100 members may have not more than 3 members on any committee; railroads having more than 100 members may have not more than 4 members on any committee.

No college, university or other institution of learning shall have more than 2 members on any committee, and no manufacturer or supply company or other organization shall have more than 1 Member or Associate member on any committee.

Retired Members

Members who have retired from active service under normal retirement procedure, regardless of whether they undertake other employment (other than sales to the railroads), may serve on committees and subcommittees a maximum of three years following retirement, but cannot hold the office of chairman, vice chairman, or subcommittee chairman, and have no voting rights. Their presence on the committee roster shall not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, or the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization. Following termination of their service on committees, retired members may continue to attend committee meetings as "visitors" subject to the approval of the committee chairman involved.

Associate Members*

No company will be permitted to have more than one Associate member on any committee, and company representation shall not necessarily be continuing. However, in the event that a railroad member on a committee becomes associated with a manufacturer or supply company (in other than a sales capacity) after retirement from railroad service on pension, and thus automatically becomes an Associate member, he shall not be deprived of membership on the committee during the period of three years,

* In applying any of the rules under the headings: Size of Committees and Associate Members, see paragraph under heading "Retired Members," and third last paragraph under heading "Member Emeritus."

following his retirement from railroad service. As regards the voting rights of Associate Members on committees, see "Voting in Committees."

The membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. Committees with Associates in excess of 10 percent of their total membership are not required to reduce the number of Associates immediately for the purpose of complying with this rule, but no Associates may be added as long as the proportion of Associates exceeds 10 percent, except as may be occasioned by the exception provided in the preceding paragraph or the exceptions set forth under "Retired Members" and "Member Emeritus."

Member Emeritus

This class of committee membership was established in 1953 in order to permit recognition of long-sustained meritorious service of committee members to committees, following their retirement and the termination of their regular membership on committees.

To be eligible for this honor, a member must be in good standing in the Association as a Member, Honorary Member, Associate, or Life Member, and must have:

(a) Retired under normal retirement procedure from active service in the company with which he has been connected.

(b) Served on the committee at least 10 years. (Executive secretary's office can furnish service record on any retired committee member.)

(c) Resigned from the committee or have been removed from the committee under the rule that retired members can remain on a committee only three years following the date of their retirement.

(d) Rendered outstanding service to the committee over a period of years.

(e) Been proposed by at least five committee members in writing and voted the honor by a two-thirds affirmative letter ballot of all members of the committee, including Associates, retired members and Junior Members—the letter ballots to be returnable to the executive secretary's office within 60 days. (Secretary's office can furnish sample type letter ballot).

The number of such members permitted on any committee will be limited to five.

Furthermore, his election as Member Emeritus must be affirmed by the Board Committee on Personnel through the executive secretary's office.

Having been elected as Member Emeritus, the member's name will continue to appear on the roster of the committee, and he will have all the rights and privileges of members except that of voting (i.e., can serve on subcommittees, should he desire, in order that the committee might benefit from his knowledge and experience). Likewise, his name will continue to be shown in the printed roster of the committee appearing in the Bulletins of the Association, and in the Assignments Pamphlet, in each case suitably designated as Member Emeritus. However, the names of Members Emeritus will not be designated by an "E" or otherwise in the alphabetical listing, railroad listing, Honorary Member listing, or Life Member listing in the March Bulletin.

Members Emeritus will not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization, or the number of years that a retired member may serve on a committee. Any Emeritus title will terminate with the death of the recipient, or in the event of the termination of his membership in the Association for other reasons.

Nothing in these rules will prevent extending the honor of Member Emeritus to a retired committee member who may have taken up, or who subsequently takes up, other employment following his official retirement.

Tangible evidence of this honor will be given to those so named in the form of a pocket card, similar in form to a railroad pass, signed and sent out by the committee chairmen.

"Guests" and "Visitors"

The previously stated rule under Committee Personnel Reorganized Annually, that "no additions to the personnel of committees will be made during the year following the official closing of committee rosters, October 1, except as provided for under the rules applying to Guests," does not preclude the attendance at committee meetings of other members of the Association, and non-members of the Association, as "Visitors," with the approval of committee chairmen.

If there are vacancies on a committee roster after the official closing of committee rosters on October 1, (i.e., less than 70), or if vacancies occur during the following year, or are definitely in prospect at the end of that year, Association members (including Junior members), with the approval of committee chairmen and the Board Committee on Personnel, can be appointed as "guests" of that committee. As such, they may attend committee meetings and participate in the committee's activities, unofficially, looking to becoming regularly assigned members at the beginning of the next Association year (March).

"Guests" must always be designated as such on the rosters maintained by the committees and the secretary's office, but their names will not appear in published committee or subcommittee reports. Creation of this class of committee affiliation is not intended to increase the size of any committee beyond the 70 maximum set by the Board, but rather to make it possible to add to "short" rosters between official roster changes.

Furthermore, one need not be either a "regular member" or a "guest" of a committee to attend its meetings from time to time. With the approval of the committee chairman, who must be consulted as regards any specific meeting, any AREA member (including Junior Members), or any non-member may sit in on the meeting as a "visitor", listen to all deliberations and participate in discussions.

Service on More Than One Committee

No member of the Association shall serve on more than one committee, except that a member may serve on two committees if one or both of the committees are among the following: Committee 3—Ties; Committee 7—Wood Bridges and Trestles; Committee 17—Wood Preservation; Committee 20—Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 25—Waterways and Harbors; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses; and the Special Committee on Continuous Welded Rail.

COMMITTEE ORGANIZATION AND PROCEDURE

Organizing the Committees

The new assignments and personnel of committees shall become effective with the close of the annual meeting in March. However, the pamphlet containing this information is issued not later than January 1 in order that committees may be reorganized immediately after January 1 for the new year's work, if reorganization has not already

been effected. Usually this information will be available to the chairmen in tentative form at least 30 days in advance of publication.

It is the duty of the committee chairman to notify new members promptly of their appointment and to notify old members of their reappointment or release. It is also his duty to reorganize the subcommittees without delay. However, in the Association year in which his term as chairman expires, he should call on his successor for advice and assistance in this regard.

Subcommittees

In general, the committees are organized to conduct their work by the appointment of one subcommittee for each subject assignment. If deemed advisable, any subject may be subdivided into several parts and a separate subcommittee assigned to each part. Committees may find it of advantage to create a subcommittee on personnel.

Subcommittee chairmen should make a report on the status of their work at each committee meeting. If they cannot be present at any meeting, they should submit such report to the chairman in writing, to be read to the meeting, or should arrange for some member of their subcommittee, or of the AAR research staff to report for the subcommittee. This rule should be followed even though the subcommittee has little or nothing to report at any particular meeting.

Organization Charts

The chairman shall furnish the executive secretary of the Association two copies of the organization chart (schedule of subcommittee assignments and personnel) of his committee, and shall advise him currently of any subsequent revisions thereof. This chart may be in the form regularly used by committees, but should not be in the form of a blueprint, on which it is difficult to make corrections. White prints are acceptable. These charts should be in the hands of the executive secretary by February 1, and should be prepared with the greatest care to insure the accuracy of initials and names.

The names of "guest" members on committees, if any, (not "visitors") should appear on the charts, but should be clearly designated as such. These names may be arranged either alphabetically among the members or grouped at the bottom of the chart as desired by the various committees. Names of "visitors" should not appear on or be subsequently added to these charts. Charts should also list (a) names of all committee members who are collaborators with other AREA committees, and (b) separately, the names of all non-members of the committee who are collaborators from other AREA committees and other organizations.

Handbook for Committee Chairmen

For the assistance and guidance of committee chairmen in the conduct of their committee work, the Association has published a small mimeographed "Handbook for Committee Chairmen", which contains the following material:

Procedures that Can Be Adopted by Committee Chairmen to Stimulate the Most Effective Committee Work.

Procedures Designed to Expedite the Conduct of Committee Meetings, Stimulate Greater Interest in Them, and Produce the Most Effective Results.

Report of a Well Conducted Committee Meeting.

Copies of this handbook are available to committee chairmen from the executive secretary's office.

Voting in Committees

Voting in committees and subcommittees on all Association matters, except as may be of a social nature, or on ballots for Member Emeritus of the committee, shall be the prerogative of active Members only; not retired Members, Associates, or Juniors.

COMMITTEE AND SUBCOMMITTEE MEETINGS

Location and Number

†Most committees find it possible to conduct their work effectively with a maximum of three meetings each year. While these meetings can be held at any time to fit in best with the work of each committee, the trend in recent years has been for committees to hold their first (organization) meeting each year in January or February in order to get an early start on their new year's work, and not wait until after the annual convention in March. However, concurrent or overlapping committee meetings are undesirable from the standpoint that they may draw several key personnel from the same railroad at the same time, or otherwise adversely affect the attendance at the committee meeting. Accordingly, before committees decide definitely on meeting dates and send out notices thereof, they should clear these dates with the secretary's office.

Subcommittee meetings can likewise be held whenever desired, either independent of full committee meetings or in conjunction therewith. The latter plan has the advantage of minimizing travel time and possibly total time away from members' offices. Where subcommittee meetings are held in conjunction with general committee meetings, they may be held immediately before or after such meetings, or during such meetings if desirable, in recesses specifically called by the committee chairman for this purpose.

†Committee meetings or subcommittee meetings should be held at points most convenient to the majority of members in order to hold down traveling time and expense, except that meetings may be held elsewhere to permit inspections important to the work of the committee or subcommittee. The Association has no funds to defray the cost of meeting rooms. Therefore, committees should hold meetings where no charge is made for such rooms, or to work out some other arrangement agreeable to members of the committee.*

Notices and Minutes

Committee chairmen shall send out, or arrange to have sent out, well in advance of meetings, copies of notices of all committee meetings to both committee members and collaborators. Two copies of all such notices should be sent to the secretary's office as early as possible for publication of meeting dates and places in the AREA News. In this latter regard, and especially if mailing of official notices is to be delayed, chairmen should give the secretary's office advance information about meetings, if possible. It should be kept in mind that the deadline for material for any issue of the News is the twentieth day of the month immediately preceding the date of issue.

Meeting notices, generally, should include or be accompanied by an agenda, preferably in timetable order, for the benefit of any members who may not be able to be in

† Revised.
* Conference Room 1218 at Association headquarters in Chicago, which will accommodate 20 to 30 people, is available for committee and subcommittee meetings to the extent that it has not already been committed for other use. Arrangements for the use of this room should be made through the secretary's office.

attendance the full time of any meeting. They should also include as much information as possible relative to any inspection trips or other features planned.

Minutes of all committee meetings should be prepared as soon as possible following meetings, and copies should be sent to all committee members and collaborators—with two copies to the secretary's office.

Reporting on Inspection Trips

In order that highlights of all committee inspection trips may be published in the News, committee chairmen should send detailed information concerning such trips to the secretary's office, or arrange to have such information sent, as soon as possible after the completion of such trips, keeping in mind that the deadline for news to appear in any issue of the News is the twentieth day of the month preceding the date of issue.

Included among details furnished should be the name of the host or hosts (companies or company representatives) on the occasion, the facilities or operations observed, and separately, the number of members and guests who participated.

COLLABORATION

Between AREA Committees and with AAR Committees

Subjects, the nature of which clearly indicates the possibility of overlapping interest of two or more AREA committees, or the interest of committees of other groups with which the Association has agreed to collaborate, carry an appended clause reading: "collaborating with ....." It is the duty of the chairmen of subcommittees having an assignment carrying this instruction to take the initiative in effecting such collaboration—by arranging for the appointment of a representative of the other interested group, should such be mutually decided as desirable, or by setting up an arrangement whereby the collaborating group will review and criticize any reports submitted to it. If a representative or collaborator is appointed, he should be kept fully advised of all activity of the subcommittee involved. Regardless of whether the assignment specifically mentions collaboration, committees should be on the alert to obtain the advice and assistance of other AREA committees or interested groups in dealing with any subject that imposes any questions of possible overlapping interest or responsibility.

The reports of subcommittees involving collaboration should be submitted to collaborators or collaborating groups whether they are for information only or involve specifications or recommended practice, and should be submitted as far in advance of filing date as possible. If they cannot be submitted prior to the committee's filing date for any reason, they should be submitted as soon thereafter as possible, and in any event prior to the annual meeting, so that if the collaborators, or the groups they represent, desire to comment thereon or to take exception thereto in any respect, such can be done in writing to the committee chairman or subcommittee chairman involved prior to the annual meeting, or in written or oral form at the annual meeting.

A committee undertaking revision of its Manual chapter should request collaboration of any committee that participated in the original development and adoption of the material under revision. The executive secretary of the Association will provide information concerning such previous collaboration.

If an AREA committee or subcommittee is asked to collaborate with another AREA committee, or with committees of any of the sections or divisions of the AAR, it shall appoint a representative to implement this collaboration, if such is mutually decided as

desirable, or it should agree, without a specific collaborator, to review and criticize any reports submitted to it. Committee members appointed to collaborate with any other AREA or AAR committees should report currently to their own committees on any matters of interest resulting from the collaboration.

The names of all collaborators, whether to or from a committee, should be shown separately on the committee's organization chart, as set forth under "Organization Chart."

With Other Organizations

Many AREA committees appoint from their membership representatives to serve as collaborators on committees of the American Standards Association, the American Society for Testing Materials, the American Concrete Institute, or other outside organizations, these representatives acting either directly for the AREA committees or in behalf of the Association of American Railroads which may hold membership in the organizations involved. In all such cases, representation in these other organizations, either initially or otherwise, is handled through the AREA executive secretary's office. Thus AREA committee nominations for representatives on these outside committees, or for changes in representatives, are made through the executive secretary's office, which transmits the nominations to the organizations, secures their acceptance, notifies those interested, and makes official record thereof.

Beyond this point the representatives carry on their collaboration independent of the executive secretary's office, but each AREA committee should keep on its organization chart a record of all of the organizations with which it collaborates, and the names of its collaborators, as set forth under "Organization Chart".

Committee members appointed to collaborate with other organizations should report currently to their own committees on any matters of interest resulting from the collaboration.

WORK OF THE COMMITTEES

Objectives

The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

Planning the Work

In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

Committees are privileged to obtain data or information in any proper way. If desired, the executive secretary will *mail* circulars of inquiry, or questionnaires, prepared by committees. Where sufficient information can be secured from members of the committee, they alone should receive letters of inquiry or questionnaires. Where a broader

representation of railroads is necessary or desirable, such letters of inquiry or questionnaires may be sent to the appropriate officer within the engineering and maintenance of way departments of selected additional roads or of all AAR Member Roads.

Only in special cases should communications of any kind be sent to officers in other than the Engineering and Maintenance of Way Departments (presidents or chief executive officers, chief operating officers, chief mechanical officers, etc.), and then only over the signature of, or with the explicit permission of, the heads of the appropriate AAR department, division or section, such to be arranged for through the executive secretary's office.

Circulars of inquiry or questionnaires should be brief and concise; the questions contained therein should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt response; should specify to whom answers are to be sent; and should be furnished in duplicate so that a copy can be retained by persons replying.

Research

It is primarily the responsibility of Subcommittee A of each committee to bring together recommendations for further study and research on the part of the committee, based upon suggestions received from other members of the Association, or as the result of its own observations within or without the railroad industry. Any recommendations for assignments in the following year which call for research appropriations should be processed with the committee early in the Association year, beginning with the close of the annual meeting in March, in order that any proposal for research approved by the committee, can be in the hands of the director of engineering research, AAR, with copy to the executive secretary, AREA, by July 1. These recommendations must be accompanied by a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigation. A request for funds to continue or complete an investigation shall include also a statement of the results obtained to date.

Maintaining Manual Up to Date

Each committee shall critically review the material in its chapter of the Manual at such intervals as to insure that it is kept up to date. It shall resubmit all Manual material for revision or reapproval at intervals of not more than 10 years. This rule, however, is not intended to encourage the reapproval of documents only at 10-year intervals. On the contrary, and especially since each document in the Manual carries a reapproval line under its heading, committees are urged to recommend the reapproval of documents each time that revisions (major or minor) are proposed, using some such wording as "Reapprove with the following revisions". If such reapproval is not requested specifically when revisions are recommended, the document will continue to carry its previous adoption or reapproval line.

However, since two or more sheets must be issued in a Supplement every time a document is reapproved without revisions, to correct the document date and the contents page or pages, it is recommended that, in the interest of avoiding unnecessary printing

costs, documents which do not require revisions should not be offered for reapproval at intervals of less than 8 or 10 years.

Group Revisions in Specific Years

While it is a healthy situation for committees to be constantly on the alert to improve their respective documents in the Manual, and while some revisions in Manual material will be of a character that will require that they be made at the earliest possible date, many changes will be of an editorial or less important character and will not demand that they be made immediately.

Accordingly, in the interest of economy, committees should, so far as possible, group their revisions in any specific document, or anywhere in their respective chapters, looking to submitting them as a group at intervals of two or three years or more, rather than separately year after year—thus avoiding the necessity for reissuing the same Manual pages, including contents pages, in successive years, to the greatest extent possible.

NATURE AND PREPARATION OF REPORTS

Form of Report

It is important that committee reports be prepared in accordance with the following instructions pertaining thereto, and the Style Standards for committee reports, as detailed on following pages in this pamphlet.

At Least Brief Progress or Status Statements to Be Made on All Assignments

†Committees should pursue their investigations on all assignments, but are expected to present detailed progress or final reports for publication only on assignments with respect to which pertinent information has been developed. However, with respect to all other assignments each year, the report of a committee shall include for each a brief statement as to the progress which has been made on it during the year, or in the event that no progress has been made, a brief statement as to the status of the project. These brief statements, which are intended to be informative to those interested in any specific subject in a year when no detailed report can be made, may be confined to as few as one or two sentences, which may be entirely adequate. In such cases, the statement should appear directly under the title of the assignment as listed in the chairman's introductory statement to the committee report as a whole, instead of the words used previously, "No report", or "Progress in study, but no report". On the other hand, if these "progress" or "status" statements, in order to be adequate to the situation, necessarily exceed 70 words, they should be presented in the usual manner as a subcommittee report, with assignment heading and subcommittee personnel. In such cases, the chairman's introductory statement should show, for the assignments in question, "Brief progress statement", and the page number, or "Brief status statement", and the page number, as the case may be.

Reports on Assignment A should not be submitted for publication.

Reports on Assignment A

In the case of Assignment A—Recommendations for further study and research, two reports on recommendations shall be made to the committee each year; (1) early in the

† Revised and expanded.

Association year with respect to any proposed new assignments involving appropriations for the conduct of research work, as set forth in detail under "Research", on page 17; and (2) late in the summer or early fall, covering recommendations with respect to new assignments for study which do not call for research appropriations. This latter report should also include recommendations as to whether any existing assignments can be, or should be, discontinued. Neither of the reports on Assignment A will be presented in the Bulletins of the Association, or orally at conventions.

Information Reports or Recommended Practice

Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, it may be advisable to submit material in the form of recommended practice, but as information only, with a view to inviting suggestions and criticism that may serve as the basis for revisions prior to the resubmission of the material for adoption at a later date. This, however, is not mandatory.

When the work has been completed on any assignment, the committee should request of the Board Committee on Assignments that the assignment be discontinued. Its last report on such an assignment should be designated as "final report" only when the committee does not contemplate further study of the subject in the near or foreseeable future; otherwise, the report should be designated as a "progress report", with the recommendation that the subject be discontinued until there are further developments.

Writing of Committee Reports*

Many progress or final reports, whether based on research or other investigation, best lend themselves to written presentation in orderly sequence or chronological arrangement, ending with any conclusions or recommendations which may have been arrived at. However, in most cases, and especially in the case of long reports, to conserve the time of members who may or may not be interested in the details of the study involved, it is recommended that reports be introduced with a brief highlight summary statement of the background, purpose and extent of the study, as may be desirable, and including a synopsis of any conclusions, recommendations or other results—this latter material to supplement a more detailed presentation elsewhere in the reports.

Reports of information, supplementing previous reports of progress, should make reference to the previous reports by Proceedings volumes, year and page number, and may include a brief review of material previously presented, but should avoid extended repetition of such material.

Use of Trade Names

Committee reports which are based upon physical research or field tests carried out by or through the research staff of the Engineering Division, AAR, may use trade names or manufacturers' names in referring to products, machines, devices or processes under test, in accordance with rules in effect with the AAR Engineering Division research staff.

* See also Style Standards for Committee Reports.

No other committee reports, however, shall contain the trade names of products, machines, devices or processes, nor the names of manufacturers, in either text or cut captions, unless in each instance approval is secured from the Board Committee on Publications prior to the publication of the reports. To seek such approval, a committee must submit five copies of the report in question to the executive secretary's office, for transmission to the members of the Board Committee, six weeks prior to the scheduled filing date of the report. If time does not permit a ruling upon the request of the committee prior to the publication date of the report in question, the report of the committee must either be altered to eliminate the trade names or terms involved, or be withdrawn, at the discretion of the committee which prepared it.

Trade or manufacturers' names are not to be used anywhere in the Manual of Recommended Practice, the Portfolio of Trackwork Plans, the Handbook of Instructions for Care and Operation of Maintenance of Way Equipment, or other comparable publications of the Association.

Illustrations in Committee Reports

Committees may use illustrations within their reports, both photographs and line drawings, to the extent necessary to enhance the value of their reports, or to preclude detailed descriptions or the presentation of detailed data which would otherwise be required. For the physical requirements of such illustrations, see "Illustrations" under Style Standards. No illustrations, within themselves, shall show trade or manufacturers' names; neither shall the captions for such illustrations use trade or manufacturers' names, without prior approval on the part of the Board Committee on Publications, as is set forth under "Use of Trade Names".

Nature of Manual Material*

The material adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Printing of Manual Material*

Material offered for adoption and publication in the Manual, except as noted herein, should be submitted in full, regardless of its publication in previous years, unless the material in question appeared in substantially identical form not more than one year before being submitted for adoption. Such material shall appear in the report of the committee that is published not less than 30 days before the annual meeting at which it is to be presented. Recommended revisions of Manual material, if extensive, shall include only the proposed material, which shall be printed in full in the report of the committee. Manual material recommended for reapproval, or for deletion, shall be presented by title and page reference only. Likewise, plans, specifications or other documents of other organizations recommended for adoption by the AREA shall be presented by title and serial designation only, e.g., current ASTM specifications, designation D 17.

* Same applies to Portfolio of Trackwork Plans.

When entirely new material is offered for inclusion in the Manual, the committee sponsoring it should state specifically in its report the exact location the material is to have in the Manual.

Letter Ballot Required of Committee*

Any action recommended by a committee with respect to the adoption, revision, reapproval or withdrawal of Manual material must have received prior endorsement by the committee in the form of an affirmative vote of two-thirds of the voting membership of the committee, such vote to be taken by letter ballot. Associates, Junior members, Members Emeritus, and retired members on a committee are not entitled to vote. Thus, it is imperative that committee members promptly consider and vote on all letter ballots, seeking the advice of other committee members or specifically qualified officers on their own roads if in doubt as to whether to vote for or against a proposal.

If a member votes in the negative on any Manual proposal, it is encumbent upon him to state the reason or reasons therefor.

PUBLICATION OF REPORTS

Dates for Filing Complete Committee Reports

To insure the orderly publication of the reports in the four winter Bulletins of the Association—November–February, incl.—in accordance with a predetermined schedule, it is necessary that chairmen file complete reports with the executive secretary of the Association on or before the dates specified in the Committee Assignments for Study and Research pamphlet.

Reports to be published in the June–July and September–October issues of the Bulletin shall be submitted in the same manner by committee chairmen, or by members of the AAR research staff in their behalf, as other reports, on a schedule worked out with the secretary's office.

The manuscript of the report must be furnished in duplicate, preferably double spaced. Piecemeal filing of reports by subcommittee chairmen is permissible only under special arrangement (in writing) with the executive secretary of the Association.

The regular annual reports of committees—to appear in the winter Bulletins of the Association—must in each case include an introductory statement, or committee chairman's report, embodying the personnel and list of assignments of the committee, as set forth under Style Standards for Committee Reports, pages 25 to 27, incl.

Portrait Photographs of Committee Chairmen

During his first year as chairman, each chairman must furnish the secretary's office a portrait photograph of himself to be used with the reports of his committee as published in the Bulletins and Proceedings while he is chairman. If this has not been done prior to the filing of the committee's report, it must be done at that time. The photograph furnished need be of no special size, but should be black and white, clear, and an acceptable likeness of the chairman. These photographs will be returned to chairmen upon request.

* Same applies to Portfolio of Trackwork Plans.

PRESENTATION OF REPORTS AT ANNUAL MEETINGS

Presentation of Reports

Reports offered as information should be presented by title or by a brief highlight outline of the contents. Material submitted for adoption and publication in the Manual* may be presented by reading the title and subtitles, but the presiding officer may, upon request, authorize the reading of specific portions of the material being offered.

Since both the degree of effectiveness with which a report is received by those assembled in annual convention, and the accuracy with which it can be reported in the Proceedings, depend upon the clarity with which the oral presentation is made to the meeting, it is desirable that committee members write out and read their presentations, and that they speak directly and distinctly into the microphone at the rostrum, raising or lowering the microphone as may be necessary to that end. In the event that written presentations are read, a copy of such presentations should be given to the executive secretary or to the convention reporter before the speaker leaves the rostrum.

Visual Presentations

The use of illustrations in the form of slides, motion pictures, etc., as a part of or in conjunction with committee presentations, whether reports or special features, shall be governed by the following rule:

Films** produced by supply companies, manufacturers, and supply organizations depicting their products or services in any form are not to be used in connection with committee presentations, either supplementing committee reports or as special features, at annual meetings, and the use of trade association films is not encouraged. However, under special conditions, where a committee desires to use a trade association film in connection with its presentation, the matter must be referred to the Board Committee on Publications for approval, through the executive secretary's office, by January 1 of the year inquestion, in order that a ruling may be secured prior to the publication of the convention program in the AREA News. Trade association films to be considered under this rule must be of an educational, rather than of a sales-promotion type, must make no direct or indirect comparisons with other products or services, and may make reference to the associations which produced them in only an innocuous way.

Oral Discussions

Comments on or criticisms of any report may be offered from the floor. When necessary to insure accuracy, or upon request, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction, misstatements, and errors of reporting, but not for the elimination of remarks.

Written Discussions

Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

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* Same applies to Portfolio of Trackwork Plans.

** Wherever the word "film" is used, it applies as well to slides and any other form of visual presentation.

Action on Reports

No formal action is to be taken by the convention on material submitted as information, whether in the form of a progress or final report.

Action on material submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.

(b) Affirmative action on the amendment of a part or parts of the material presented, followed by adoption as a whole as amended.

(c) Adoption of a part, complete in itself, and referring the remainder back to the committee for further consideration.

(d) Recommittal with or without instructions.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

MISCELLANEOUS

Memoirs

The Association has developed a complete set of rules with respect to memoirs in committee reports or elsewhere in its publications, covering the scope, preparation and presentation of such memoirs. Copy of these rules, as well as the Association service record of any deceased member, can be secured from the executive secretary's office.

Letter Ballot of Membership

When and as required between annual meetings, recommendations for the adoption, deletion, revision or reapproval of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

The Board of Direction, acting under the provisions of paragraphs 6 (a) and 11 of Article VII of the AREA constitution, has the authority to amend, delete or revise Manual material at any time, subject to later confirmation or rejection by the membership, submission to the membership to be effected either by means of a letter ballot immediately following such Board action, or by a motion presented at the annual meeting.

Review by Association of American Railroads*

All material adopted for publication in the Manual and all recommendations for the revision or withdrawal of Manual material shall be referred to the vice president, Opera-

* Same applies to Portfolio of Trackwork Plans.

tions and Maintenance Department, Association of American Railroads, for review, before distribution is made thereof to holders or purchasers of the Manual, or parts thereof.

Publication and Distribution of Annual Supplement to Manual*

Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those sheets that have been withdrawn by action of the Association.

In order that committee members who have purchased individual Chapters of the Manual in connection with their committee work may keep these separate Chapters up to date, the secretary's office will make available to them annually, through their committee chairmen, those supplement sheets required to this end.

Publication of Abstracts by Technical Journals

The following rules will govern the releasing of material for publication in technical journals:

Committee reports to be presented at an annual meeting will not be released for publication until after presentation to the annual meeting. Special articles, contributed by members and others, on which no action by the Association is necessary, will be released for publication in technical journals only after issuance in a Bulletin; provided, application therefor is made in writing and proper credit is given the Association, authors or committees presenting such material.

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* Same applies to Portfolio of Trackwork Plans.

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